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THE QUARTERLY REVIEW of BIOLOGY



WHY ARISTOTLE INVENTED THE WORD ENTELECHEIA (*Continued*)

By WM. E. RITTER

SECOND FOREWORD

LETTERS evoked by the portion of this article published a year ago, have shown me that nowhere in the substance of the article do I make clear the ground of my interest in the problem discussed. That ground is, first and most deeply, my interest in Nature—in all Nature—not in a few parts of it that happen to strike my personal likes or dislikes. This interest grew, slowly and long, sometimes interruptedly but never menacingly, and led me, finally, to "accept the Universe."

Though always hesitant about being too hard on the Universe, even on the parts of it that were least to my taste, it was not till after my period of infallible knowledge about it and cantankerous criticism of disapproved parts of it (period, i.e., of early and middle life) that I became duly impressed with the serene way Nature gets along in the face of fault-finding with her. Not till then did my acceptance become whole-hearted.

But other factors contributed to the acceptance. One of the most influential of these was the clarification of my understanding that we ourselves are parts of the Universe in so vital a fashion as to be privileged, indeed compelled, by the very nature of the case, to contribute to making the Universe what it is on any particular day of our lives.

Seeing that by no hook or crook can we do otherwise, it is best, then, for us to accept the Universe—as a reality. But, seeing further that we cannot avoid contributing to changes in that reality, it is best for us to see to it as far as possible that these changes are good for us.

Vast scientific researches have made the interrelated-

ness of parts of nature far more manifest to us than it has been to previous generations. We ourselves and the myriad other living things, likewise the earth, the sun and all the heavenly hosts, without which we neither live nor move nor have any being—of such does reality turn out to be.

Travel on this highway led me in due time to recognize the need of some one word or phrase for expressing a truth about reality that is not expressed by any English word. Aristotle's famous word *entelecheia* comes very near filling this need. The phrase "complete reality," adopted by W. D. Ross as an English equivalent for the word, is justifiable so far as my very meager knowledge of the Greek language enables me to judge. "Fulfillment" Professor Ross kindly suggests now by letter as a possible single-word equivalent. This would be fine if it could include the idea of genesis as unmistakably as does "complete reality;" for the inclusion of this idea is unquestionably one of the chief merits of the word.

These paragraphs are a revision of the *Foreword* to the installment already published. Their purpose is to make clearer my primary interest in this study. But I want also to make clear my secondary interest, the question of Aristotle's attitude toward, and conception of, Nature. Intrinsically the man was cast in the same spiritual mold, according to my view, that all the great naturalists of all the ages have been cast in.

Of these naturalists I mention only two, restricting myself thus for a reason that will appear as we go along. The two chosen are Charles Darwin and T. H. Huxley.

In several late publications it is pointed out that all naturalists may be ranged in two great subdivisions. For one of these the terms *naïve* and *analytic*, for the

other *philosophic* and *synthetic*, have been suggested. Neither the naming nor the defining of the groups is particularly easy. There is, however, one characteristic that is of almost unfailing diagnostic value. That is the presence or absence in a given naturalist of interest in, and effort on, the nature of knowledge itself, the *epistemology* of traditional philosophy.

Any naturalist who "accepts the universe" in the sense above indicated, i.e., not only because he can't help himself but because he is eager and glad to, thereby commits himself to some serious attention to the problem of knowledge. This for the obvious reason that having accepted himself as part of the universe, he has accepted all of his activities. Among these activities are his getting and using of knowledge. So it turns out that every such naturalist belongs willy-nilly, to both the subclasses of the class of naturalists we are recognizing.

But so well-nigh universal is the custom among modern students of the natural sciences to limit their studies to the external world that any tendency otherwise has tended to bring ill repute upon the venturer. To be "objective" is the unfortunate term chosen as descriptive of the proper method of procedure. The need for more critical attention to the meaning of this and many other words used by naïve naturalists is one of the things that makes it important for every naïve naturalist to become also a philosophical naturalist in some measure. (In anticipation of the legitimate query as to what my pretensions to being a philosophical naturalist rest on, I refer to a few, rather fragmentary, writings of this purport which have thus far been published: Ritter and Bailey, 1927, 1928, 1929, Ritter, 1929, 1931.)

So prodigious in size and complexity of structure and action is the portion of nature outside of us, and so fascinating is it, too, that it is neither surprising nor deplorable that the vast majority of naturalists should occupy themselves very largely with the study of this portion of nature. But it is also neither surprising nor deplorable that a considerable number of naturalists should be more interested in the processes themselves of getting and using knowledge than in the things known and used.

Of all those who have accepted nature the most fully and devoted themselves most single-mindedly and effectively to the study of her in the fashion we have denominated as naïve, no one seems to have equalled, much less to have surpassed, Charles Darwin. The implication of this, that the exalted place held by Darwin among scientists is due to his labors as a naïve naturalist to the almost entire exclusion of labors as a philosophical naturalist, is likely to come with something of a shock to most, perhaps to all, scientists. Yet in so far as occupation with the prob-

lem of knowledge is taken as a criterion of philosophy, Darwin's aloofness can be shown with great clearness. All professional philosophers who have given attention to the point seem agreed on this. The truth of it deserves more attention than it has received.

T. H. Huxley, on the other hand, is allied with the philosophical as well as with the naïve naturalists. His *Hume*, *Hume with Helps to the Study of Berkeley*, and portions of his articles on *Agnosticism* led him far into the problem of knowledge. These writings mark him as a philosophical naturalist quite as definitely as his writings on marine invertebrates, on fossil vertebrates, and on human anatomy and physiology mark him as a naïve naturalist.

In unpublished manuscript of the larger work of which this article is a part, I draw quite a "parallel lives" of Aristotle and Huxley. In the likeness in type of the two, nothing stands out more sharply than their common characteristic of *naïveté* on the one hand, and *philosophicness* on the other hand. Both did extensive researches on marine invertebrate zoology, that is to say, on animals far down the zoological scale in one direction; and also on man and the higher vertebrates in the other direction.

The conclusion I reach about Aristotle may be epitomized as follows: In original responsiveness there is every reason to suppose his bent was toward accepting nature in the sense indicated. His childhood and early youth, lived in a home environment of medicine and surgery and a neighborhood environment of hills, valleys and streams, and of sea and shore, as these entered so largely into the physical geography of the almost primitive Macedonia of that time, would be especially favorable for such a bent. A flood of particulars—sensory particulars—largely primal, never-ceasing, ever-varying, poured upon the boy from all sides. Research of late years has convinced us that the influence of environment on the mentality of young children is such that conditions like those under which Aristotle lived as a boy are by no means insignificant for the rest of life.

Then came the transplantation of the youth to the vastly different environment, that of a city and a culture of peerless grandeur. Athens and the Academy!

The flood that poured upon the youth and young man for almost twenty years—what a contrast it was from the flood that had poured upon the boy! Universals now, not particulars, were its chief substance. And this meant thoughts more than sense perceptions. Subtleties of description, dialectic and rhetoric more than names, descriptions and classifications of observed objects were now the constituents of the flood.

But no environment whatever is the whole story for any living being. The being itself is an essential—

an exceedingly essential—part of the story. Particularly is this so if the being is as highly constituted as is a human being. Most particularly of all is it so if the human being happens to be an Aristotle.

Readily as the youth responded to, profoundly as he was influenced by, the stream that flowed from the Athenian and Academic environment, this stream could not entirely obliterate the influence of the flood to which he was subject as a boy. Consequently, as he neared the maturity of manhood and passed beyond the precincts of the Academy, he began to feel, we may conjecture, that the kind of thing he experienced years ago in Macedonia was not less real than the kind he had now experienced in Athens, and hence that the two must be in harmony at some great depth of truth.

Distressingly scant though the biographical evidence is, it justifies the surmise that at this critical period of his life Aristotle caught a gleam that led him to become, finally, the "type specimen" (this technical term I am entitled to use from my vocation as a taxonomist in natural history) of the subspecies philosophical naturalist, of the species naturalist, according to our classification.

The truth, a gleam of which I imagine him to have caught, concerns the phrase: "accept the universe." Is the phrase to be taken as merely these two words with some ill-defined meaning attached to them? Or is it to be taken with a meaning that corresponds to the objective truth about the Universe and the emotional-rational truth about accepting? The constitution of the universe is such that it must be accepted both in its state of wholeness and in its state of compositeness. He who attempts to accept it on any other basis than its *oneness* on the one hand, and its *manyness* on the other hand, makes the attempt at the peril of his own oneness, or integrity. As to size and number of parts, the universe has no limits so far as observational knowledge has been able to ascertain. As to the creative and sustentative powers of the universe, there are no observably demonstrable limits to its powers of sustaining already existing parts and of producing new parts.

Of these truths about the universe, Aristotle caught hardly more than a gleam. How could he have done better? So small a portion of the universe, and so few of its parts were accessible in his day, the wonder is that he should have caught even this much.

But catching even this much of the truth sufficed to endue him with a sensitiveness to all the things round about him, with curiosity about their deepest meaning, and with determination to satisfy himself on these scores. Accordingly, when about forty years old he laid out for himself the task, recognizable by us now as inconceivably vast, of acquiring a knowledge and

understanding that should be coextensive in size and commensurate in detail with the Universe.

He would produce a science of the whole Universe in contradistinction to the science taught at the Academy which he seemingly (and I think rightly) regarded as in effect an attempt to avoid accepting exceedingly important parts of the Universe. The historic fact and the probable significance thereof that Aristotle turned with greatest seriousness to the study of nature *after* his extensive studies in the Academy, appear to be gaining recognition by specialists in the Aristotelian writings. All naturalists measurably acquainted with the whole situation would, I think, agree that such pretended natural knowledge as that presented in the *Timaeus*, for example, could be no more acceptable to Aristotle as a naïve naturalist than the Platonic Forms and Ideas were acceptable to him as a philosophical naturalist.

But the undertaking that Aristotle proposed for himself was gigantic even in his day, relatively small and simple though the Universe then seemed. As a naïve naturalist he must describe, name, and classify all its lands and waters and the inhabitants thereof; the sun, moon and stars; the blue sky; the air with its winds and storms; and whatever else might be contained in the flood of sensory experience. Furthermore the causes, potencies, and actualities of all these, he would have to consider.

The attempt to carry out this part of his program was responsible for bringing upon his head the modern withering criticism of superficiality. From spreading himself over everything and consequently being thorough in nothing, his labors, though universally admitted to be almost unsurpassed in volume, are viewed by some exact scientists of our day as valueless if not worse. It is true that much of all natural science since the Greek period may be looked upon as additions to Aristotle's beginnings and corrections of his errors. This is particularly true for the sciences of inanimate nature. But there is much truth in it too for the sciences of animate nature—the sciences in which his chief researches were made.

But, foundational as were Aristotle's attributes as a naïve naturalist, more definitive of him were his attributes as a philosophical naturalist. For the problem of knowledge was his main concern, as everybody knows, in his "*First Philosophy*" (called *Metaphysics* by later students) and in his group of treatises generally called by his successors the *Organon*, or *Logic*. The final test of how far the man succeeded in carrying out his grand project must be sought here.

Far be it from me to presume myself competent to apply this test fully. My task is much smaller. It is only that of finding the use Aristotle made of his

term *entelecheia* in his treatment of the problem of knowledge, with a view to learning whether he could use it, when speaking as a philosophical naturalist, consistently with his use of it when speaking as a naïve naturalist. My efforts speak for themselves, chiefly in the portion of this article here presented. Since they contain my most important restrictions on, and deviations from the Aristotelian teachings I make this expiatory remark: Allusion was made above to the patent fact that the vast progress of natural science since Aristotle's time has consisted largely in adding to and correcting, what he did. Adding and correcting thus is in the very essence of natural knowledge. Especially is this true of such knowledge as belongs to the realm cultivated by naïve naturalists. Why, then, should we not expect that something of these processes would operate in the realm cultivated by philosophical naturalists? But the nature of scientific and philosophic knowledge would justify the expectation that addition and correction would play far lesser parts here. Generalization, abstraction, ideation, reason, bringing great masses of sense data under a common viewpoint, are just what make philosophical naturalism as an indispensable correlate of naïve naturalism, the two together constituting Naturalism in its full meaning.

Whatever of merit or demerit may belong to Aristotle in mankind's effort to know itself and the world of which it is a part, this much, according to my interpretation, will stand to his credit as long as this desire and effort shall continue: He saw, as none before him and few since, have seen, that success in the Great Enterprise is contingent upon the acceptance of the Universe both as *One Whole* and as *Many* parts taken one by one, to constitute the whole. Any interpretation of Aristotle that would class him as a sub-naturalistic atomist or elementalism or as a supra-naturalistic "holist," is untrue to the deepest nature of the man.

So far as the ground of this interpretation is reducible to a minimum of single words, those words are: *Δύναμις* (*dunames*), *power, potentiality*; *Ἔνεργεια* (*energeia*), *activity, actuality*; and *Ἐντελέχεια* (*entelecheia*) *complete reality, fulfillment*. Of these the last is far-and-away the most important since it takes account of not only the whole, any whole, but of all its constituent parts, and of its coming to fulfillment by a course of individual development.

A postscript to those, some of them friends or acquaintances, others personally unknown to me, who have made valuable comments and criticisms on the portion of the article already published: It is a great satisfaction to me, and will, I hope, be reassuring to readers generally, that in every case these commentaries (some of them from highly competent technical

sources) agree that the main point of my contention is well taken.

For reasons that seem obvious it is impracticable to take advantage now of all the useful suggestions given me. But when and if the article comes to publication in the whole of which it was written as a part, these and such further suggestions as may come, I certainly count on for improvements of that whole.

II

CAUSE AND THE WHOLE-AND-ITS-PARTS

In the first installment of this essay we carried the examination of the concept of a whole-and-its-parts, as worked out to a large extent by Aristotle, far enough to see something of what is involved when the concept is applied to individual human beings. But very much more remains to be seen in this direction.

The "complete reality" (*entelecheia*) of such a being certainly includes the entire gamut of its conscious (as well as infra-conscious) experiences.

Now, nothing is more certain than that within these experiences are the most exalted aspects of rational and spiritual life on the one hand, and the most unqualifiedly physical aspects of nutritional and sexual feeling and action on the other hand.

What, from this standpoint, did Aristotle do for these aspects of human life? Two negative but yet important answers are readily given: (1) We may be sure he did not overlook or minimize the reality and importance of either aspect. We know him to have been too good as both naturalist and philosopher for that; (2) we may be sure he could not possibly, however capably he might try, be fully successful as to either aspect. His knowledge of the structure and actions of animals and of natural bodies generally was much too scanty and error-pervaded. Consequently, in striving to answer our question, we must follow the course pursued thus far in this study. We must examine what Aristotle

knew and *thought* and *did* in the light of what moderns *know* and *think* and *do*.

The examination may well begin with a more careful scrutinizing and appraisal than we have yet made of the factual data now in our possession in their bearing on the problem of the causal relations between a body in its wholeness and the parts of which it is composed. Readers of the Aristotelian writings hardly need reminding further of the relation of this problem to Aristotle's "our usual method of investigation," the method, namely, of analyzing a whole into its parts. But sufficient notice has not yet been taken of the relation between this problem and the Aristotelian ideas of a whole-and-its-parts and of form and matter. With nearly all of modern science the notion has much the force of a religious dogma that to analyze a compound into its least parts is to explain that compound causally. Or at any rate, so the dogma holds, if in a particular case the explanation is not quite ultimate, this is because the analysis has not yet gone far enough. The ultimate goal of explanation is, *per se*, where analysis ends. So far as the inner nature of compounds is concerned, causality works in one direction only, i.e., from parts and elements toward the whole. Indeed, so far as concerns the nature of compounds, it is hardly too much to say that cause is conceived to be that which the parts, especially the least parts, do to and for the compounds they compose.

Such a notion as that a body in its wholeness may act causally on its parts not only has almost no place in modern science, but with the ultra-analytic school such a notion is heresy and should be treated as such. Cause must be so conceived and defined as to exclude the notion.

Something of the scope and depth of the Aristotelian disagreement with this posi-

tion is known to everyone acquainted with the Aristotelian writings.

The involvement of the idea of cause in these writings is of course one of the characteristics and one of the specially hard and controversial things about them.

A brief examination of this question appears the more opportune at present because of what General Smuts has given us (or rather, has not given us) on the question. No one can, I think, read *Holism and Evolution* and other writings of this author on this general subject without being deeply impressed. But for me, at least, the impression is considerably mixed owing to the fact that I find no evidence, either direct or indirect, that the author has studied seriously, if at all, the works of Aristotle in their bearings on the problem of wholeness (Smuts, 1925, 1931).

Modern science, biology especially, has taken much cognizance of some of the toughest of these things. A general discussion of the controversial matters here is not to be thought of, nor would it be more than slightly relevant to our main purpose. There are, however, three things in the Aristotelian teachings about *cause* that are sharply relevant to our purpose. Two of these, the material cause and the formal cause, have been discussed almost endlessly in the past. The third, the principle of multiple cause, appears to have received little if any close attention. Yet the evidence that Aristotle recognized this principle to some extent is conclusive and seems more significant for estimating the relation of his knowledge and thought to modern knowledge and thought than has been appreciated. One piece of evidence on the point is this:—Following the definition of the four causes in the "Philosophical Lexicon" we read: "These, then, are the causes, and this is the number of their kinds, but the varieties of causes are many in number. . . . Causes are spoken of in many senses" (*Metaphysics* 1013^b 28–30 Ross trans.) Although many illustrations, by inference at

least, of like purport could be given, the statement itself will have to suffice.

We turn now to what I interpret as really a modernization of one aspect of Aristotle's formal cause. That aspect, expressed in terms consonant with the growing demands of theoretical biology, is that to the extent (which is certainly large) that Aristotle's idea of form is the lineal forerunner of modern morphology, his formal cause is the lineal forerunner of the idea that a living compound whole is as truly causal of the organism as are the parts or elements of which it is composed. I venture to express, dogmatically at first, what it seems to me the modern position is or soon must be, on this question: *Every whole, especially every living whole, acts causally on its parts as well as being acted on causally by its parts.*

The interaction of the parts of any body to make that body alive is now so far understood that it is doubtful if the most extreme particleist in any of the sciences of living nature would defend the proposition that any of the parts, even the most minute and supposedly potent, produce, just *per se*, the 'aliveness' of an organism. True, one often hears that the atoms of modern physics—or perhaps more exactly the electrons and protons, one or both,—must be alive. But those who express this view admit, of course, that this atomic life is quite different from the obvious life of any particular plant or animal. For nobody would seriously argue that an oak tree's aliveness and a man's aliveness are exactly the same, even though the electrons and protons of the two are the same.

So it seems fair to say that there is now general agreement among competent students that living wholes are dependent on the interaction among their parts. The reciprocal action of the parts—their reaction to one another—their causal action, each upon each—are productive of results

in the form of bodies and actions different from the parts. There is no longer any factual or critically logical ground for holding that because a bacterium or an amoeba or a jelly fish or a dog or a man is alive, therefore the atoms of carbon, nitrogen, oxygen and the rest are alive and were alive before ever they combined to make these organisms. The indubitable facts compel the conclusion that the potentialities of the atoms are such that when they interact among themselves and combine to make large compound bodies, if the interaction and combination occur under proper conditions, the potentialities of the atoms become actualities as the characters or qualities or attributes of the particular organisms. Even vitalists, especially if working biologists, would probably go this far in recognizing the potency of the parts of organisms.

Now this modernly requisite conception of potentiality and actuality is in full accord with the general tenor of the Aristotelian teaching.

Crucial for the interpretation of the phenomena is the question of the "proper condition" for actualizing the potentialities as indicated. And here the Aristotelian theory, resting largely on logical grounds, is distinctly superior to modern theory, which also rests largely on logical grounds.

With the superiority of the Aristotelian over the modern logic in the case we shall not here concern ourselves since we have touched its ganglionic center so to speak, under the heading "The Law of Identity." "Law of Contradiction" would probably have been more appropriate for the discussion here referred to—if the laws of "formal logic" must be noticed at all in such discussions. But the concrete facts are, of course, the point: A human individual in the baby stage of his development *is* in that stage and is *not* in the

adult stage. Otherwise stated the characteristics of the adult are present in the baby *only potentially*. Much shoddy thinking about, and worse dealing with, children seems to result largely from disregard of these psychobiological facts. Our main point now is concerned with fact rather than with logic. For we are going to point to facts with which the Aristotelian concept of formal cause (as defined above) is more easily harmonizable than the concept of elemental-atomic cause of present-day biological orthodoxy.

NUTRITION, METABOLISM, AND THE WHOLE-AND-ITS-PARTS

The chemistry of assimilation and metabolism in living bodies is now too well understood to permit any informed person to repeat, except as a reminiscence or a joke, the old epigram, "One is what he eats."

The facts-in-common between the basic processes in an organism and in a flame are an explanatory commonplace of our day.

Consequently, just as no ordinary mortal can be fooled into believing that the stick of wood alongside his fireplace, or the surrounding air are "essentially the same" as the flame and the warm room that wood and air will cause if they come together in the right way—even as little can such a mortal be fooled into believing that he or any of his friends are "essentially the same" as the food they eat, the air they breathe, and the water they drink.

In connection with this allusion to the similarity between respiration and combustion further reference should be made to the great part played by the concepts of potentiality and actuality in Aristotle's thinking and the seemingly insignificant part these play in the speculative thinking of some moderns. Of course, no "dirt farmer," or cook, or engineer, or practical chemist, or maker or user of explosives, or, in fact,

anybody faced with almost any practical problem, gets on independently of the principles though he may not think much about them.

If, however, we attempt to push the organismal conception beyond the certainty of the interaction of parts to produce the living organism, we find ourselves in trouble. Especially are we troubled if we try to push the conception with reference to human organisms. However, we shall now see that if one singles out himself as the human organism on which to test the conception, he gets important help for the general problem.

I am fully convinced that the mental and physical activities involved in my thinking and writing these lines are caused by the way my physical parts utilize the air I breathe, the food I eat, and the water I drink. But I am absolutely certain no physiologist or physicist, or chemist, or any combined efforts of theirs can discover by analyzing me exactly how my parts act and interact with the substances I take, to produce these effects. My certainty is thus positive for the reason that by the time my analyzers reach the crucial stage of their laboratory undertaking, *I*, the living organism now sitting at my desk, thinking and writing, will be dead and gone for several days at least. In other words, my analyzers will be trying to do one or the other (or both) of two impossible things: (1) Trying to observe causal processes *in actuality* which went on and were ended, many days or weeks ago; or (2) trying to discover by deductive reasoning parts and substances that possess the potentialities for accomplishments of man which the analyzers know, but only from the records. They learn nothing about these accomplishments *from their analyses*. The things they are trying to do we are sure are impossible first and foremost from examining critically our own knowledge-

getting processes. But our assurance is greatly strengthened by learning that this impossibility was recognized more than two thousand years ago by Aristotle and has been recognized time and again since by competent students.

Accordingly, being certain that, however far laboratory study of the parts and substances of me may go in explaining my thinking, and my acting generally, it is bound to fail at the most crucial point, no argument, just as such—argument, that is, that may profess to transcend entirely all sense data—could convince me that *I*, myself *whole*, am as truly a *vera causa* of all I am and do, as are any of the parts of me or the substances which enter into my composition. After admitting, fully and gladly, all that analysis can prove that my parts and external substances contribute to making me what I certainly am, I am not fully explained until I my very self am recognized as also causal of me.

At least to the extent that my thoughts and acts and conscious experiences differ from those of any other person, I see no causal explanation of the fact consistent with great masses of indubitable natural knowledge other than that *I* in my individual wholeness act through my parts to get from the air I breathe, the food I eat, and the water I drink, the energy necessary for producing the thoughts and acts and conscious experiences thus uniquely mine. It seems that *my assimilation and metabolism are as specifically mine as are any of my conscious acts or other conscious experiences*.

But as I look around I find great numbers of other individual organisms so like myself but also so differing from me and all other individuals, that I am obliged to suppose they, too, are uniquely privileged in their assimilation and metabolic powers.

Nor is this all. Extending my inventory of other individual organisms I notice not only endlessly slight (relatively) differ-

ences among great numbers of individuals, but also endless differences that are by no means slight, and that are endless in kind and grade. For instance my inventory contains not only white men, black men, red men and so on, but fishes and trees and amoebae. And then I recall that by almost endless labors men have discovered that, *mirabile dictu*, all these endless kinds and grades of individuals exist, grow, and act by taking from the world external to them the same few simple materials and using them to their own individual needs and ends, just as I do!

How could any botanist or chemist or philosopher explain, causally, an eucalyptus tree and an oak tree that have flourished for fifty years within a hundred yards of each other, their roots buried in soil that any expert would pronounce essentially the same and their branches, leaves and blossoms bathed in the very same air and sunshine, without including the two trees themselves as causal factors—if any such factors are recognized?

The truth is, the thing cannot be done. Nor can it be seriously attempted without ignoring or perverting some of the most deep-rooted and wide-reaching principles of both common and technical knowledge. And such attempting is the sort of thing Aristotle characterized as the childishness of trying to explain the obvious by the unobvious.

This problem of the way living beings, men particularly, use materials from external nature is so important that we shall do well to look at it from still another angle.

Reflect on what Mayow, Priestley, Scheele, Lavoisier and whoever else had a hand in the business, did in discovering oxygen. Really they did not begin by discovering a gas, having this name. They began with certain observations, that is to say with certain sense experiences. As they

worked along, these experiences became to them sense data, which they recognized as the sensible qualities, or properties of a certain gaseous body. What Mayow called fire air (*igno-aerian*) and Priestley dephlogisticated air, represent this stage in the course of the discovery. Finally came Lavoisier who by adding certain quantitative observations to the (chiefly) qualitative observations of his predecessors, recognized the body as not really a kind of air, but so distinct as to deserve a name by itself. The word, oxygen, which he devised, was chosen, notice, because of what in his experience, was its most characteristic property, that of generating (in combination with other bodies) still other, compound, bodies that were "sharp" to the taste and in their action on many bodies. The newly discovered body was acid-producing.

Every step in this discovery as in every other that was ever made in any division of natural knowledge, involved basically sense experiences, accepted later as sense data, still later as sensible qualities or properties of external bodies, which qualities, or properties are peculiar to, or characteristic, or definitive of the bodies. In other words, the *observed*, or *sensible characteristics of any body are not only peculiar to that body, but are those things by which we KNOW THE BODY.*

And now comes a still more vital point. It is known to everyone that the history of the discovery of oxygen (Mayow to Lavoisier, about a hundred years ago), is involved with the basic similarity between respiration and combustion—between breathing and burning. So much a part of common knowledge is the dependence of the activities of living bodies, at least of all higher plants and animals, on oxygen, that the merest reference to it is enough for this discussion.

See then the conclusion that the discovery

of oxygen seems to force upon us: *While Mayow and the others were discovering, by their powers of observation, the sensible properties of this gaseous body, they were also demonstrating by their powers of living that this same body possesses life-giving properties that are discoverable only by LIVING AND PERFORMING EXACTLY THOSE ACTS THEY DID PERFORM IN MAKING THE DISCOVERY.* (Ritter and Bailey, 1928, p. 250)

The incalculably vast number of potentialities of oxygen which this interpretation requires might stagger, even mystify, us except for the recognition that the potentialities of oxygen, like those of all other bodies, are really non-existent for us mortals except as actualized by the interaction of the bodies with other bodies. Were it not for the living that was done by Mayow and the others, the life-giving potentialities of oxygen would never have been actualized and discovered. Nor is this all we know that does much toward saving us from being hopelessly mystified by our conclusions. Not only are living men and other organisms necessary for actualizing some of the potentialities of the oxygen, but various familiar substances which constitute the food and drink of organisms are necessary. Carbon and nitrogen are particularly in evidence as such necessities. The truth is, the entire mass of knowledge possessed by us moderns is available as aids to making such a conception of oxygen (and all the other chemical elements upon which life depends) intelligible to us. It is *intelligible* to us because it is the reasoned counterpart of our *experience* as living organisms.

If we desire to think the problem or the basis of some theory of cause, we ought to find, it would seem, genuine satisfaction in the concept of multiple cause. For here many supporting facts from modern science are available, as well as the fact

that the idea is recognizable in the history of knowledge and thought as far back as Aristotle at least.

One may justifiably wonder, it seems to me, whether the bewildering discoveries being made by physics and chemistry in our day on atomic structure and action may not mean that sensory knowledge is not now touching the hem, so to speak, of the garment that has been and is the common experience of all living things.

THE "WILL" AND THE WHOLE-AND-ITS-PARTS

From the light one may gain on the general problem of a whole-and-its-parts by studying himself as a chemical transformer so to speak, and then by asserting his "natural rights" as such a transformer, I am encouraged to take a still farther step in the same direction.

The aspect of myself to which I now turn is that of my wanting things, resolving to try for them, and finally actually carrying out the resolution as far as possible.

All this is so obviously at bottom an affair of my very own that no one would, I presume, venture to interfere with me much. If, however, I set up the contention that the "I" is myself whole, is I, *Body-and-Soul, Mind-and-matter*, all an inseparable One, I am pretty sure to be reminded that the interpretation almost universally accepted in such cases is very different from that I suggest. True, it would probably be granted, that my wanting and the rest are undoubtedly mine, "But," my correctors are quite sure to remind me, "it is your will and its adjuncts that really wants, resolves, and executes. Of course this is largely dependent on your body parts, especially when the executing stage is reached. But so well-nigh universal has been, and still is, the idea that human experiences of the sort you mention are the expression of something or other not closely dependent, at least not dependent in a fashion that is analytically demon-

strable, on your body parts and substances, it seems the view must have a solid basis of truth and so should be retained. Furthermore, since the term, Will, appears to be as good a name as any for this analytically undemonstrable something, that, too, may as well be retained with its original meaning."

So here we are, quite innocent of intent or even of preawareness, face to face with the interminable problem of the will. But since the path that has led us to it is clearly marked though not much traveled, we can not honorably avoid facing the problem squarely. And here again I must intrude my personal experiences.

Being a hopeless addict to the habit of reading in bed at night when by well established laws of health I should be asleep, I suddenly find myself wanting an orange. Knowing that there is a bag of this fruit in the adjoining room, I decide that as soon as I have finished the chapter I am now reading ("Reflex Action and Theism" in Wm. James' *The Will to Believe*) I will go and gratify my want (want of being nourished and of having certain other felt needs satisfied). The end of the chapter having been reached, I close the book, lay it aside, throw back the bed covers, get out of bed, go to the orange-containing room, reach into the bag, bring out an orange, carry it to a table, open a drawer which I know contains the tools convenient for preparing the fruit to be eaten, and so complete the preparation for gratifying (satisfying?) the wants now upon me.

Then I go back to bed and think about what I have done.

Two points connected with my doings seem deserving of special attention. I notice that had I supplemented all the pronouns referring to myself—"I," "me," "my"—by such nouns as mind, memory, thought, desire, satisfaction, I should not thereby have increased by one iota my un-

derstanding, my achieving, or my sense of benefiting. If I say I have a desire or feel a need for an orange or anything else, I surely mean no more than if I say I desire or need the thing. Whenever I speak of a thought or a conception as "entering my mind" I am only saying in a round-about way that I think or that I conceive, so and so. The purposes in making our activities into abstract nouns seem various and are often far from obvious. There is one purpose, however, that is clear enough, in general: It is a convenient way of shunting into the background the puzzling question of exactly why and how one acts as he does. When I can say "my choice is made," I have a feeling of unequivocalness, of finality, about what I have done, that is more satisfying than if I say "I have chosen." In the latter case I feel somewhat more inclined, perhaps impelled, to explain, to analyze, what I have done.

Since these sentences were written it is with very great satisfaction that I have read the just-published book (Korzybski, 1933) in which the whole subject of the use of generalized and abstract words is given the most thoroughgoing treatment it has ever received, so far as I know.

Notice with me now what I do when I decide upon a particular course of action and then really act in accordance with that decision. When I decide in conformity with my wanting an orange, to go, at a specified future time, and do the things I believe will satisfy my wants, the question of what and how many parts of me are involved in making the decision, is surely a very complex, and at some points, obscure question. Thanks, however, to the splendid researches of modern psychologists, physiologists, histologists, and biochemists, I have, or may have, much of the answer to the question. But not an item in all this knowledge will have any meaning for the special case in hand, without *me*, a living organism, as the field of operation.

But it is when I put the decision-making aspect of me to the test of my executing aspects that many of my most concrete, most conspicuous parts, prove their rôle in the case. Throwing back bed covers, getting out of bed, walking to the next room, and all the rest—the body members involved no five-year-old will hesitate to name. Nor will anybody of down-right intellectual honesty refuse to grant my contention that they—hands and feet, for instance—are truly mine and that I truly do move them. Furthermore, some of my less familiar, though no less certain internal members no one would think of ignoring or of questioning my ownership of—nor the fact of my using them. But when the question is raised of what, exactly, all these internal parts are and how many there are of them, some of the difficulties in the way of getting direct observational answers are undoubtedly very great. My chromosomes and genes, for instance,—not to speak of my atoms, electrons and protons,—how am I to learn their part in the business? Accordingly the expert analysts might proceed, typically and legitimately, to give hypothetical answers, answers, that is (if really legitimate) intended to be provisional only. And "provisional" would have the two-fold reference of making the answer that would seem most likely to be true, and of aiding further effort toward the real, i.e., the observationally based, answer.

Notice now what my own attitude and view must be in all this. So far as my experiences, whether conscious or unconscious, were concerned, the observational distinctness or indistinctness of the parts involved, is not of the slightest moment. My desire for an orange, my decision to go after one, and my actual going, getting, and eating it, might have been as truly portions of my conscious experience when I was a five-year-old as when I was a seventy-

five-year-old. Such objective knowledge of my parts and their activities involved as I have gained by hook or crook, has not cut the least figure in the experiences themselves. Nor does it matter a scintilla, so far as my conscious experience is concerned, that the parts of me by which I want an orange defy the analyst's efforts at complete discovery. Such parts serve me just as certainly and readily as do such crass parts as hands, feet, and mouth.

Well, I ask myself, have I real ground for supposing that any desiring, deciding, resolving, and executing I may do in any realm or at any level, are teetotally different from my doings in the realm of orange eating?

True enough, my wantings, decidings, resolvings, and executings, involved in, for example, the part I took in producing the Scripps Institution of Oceanography, were remarkably different from those in the citrus example. But, really, so far as I can see, the difference concerned goal and operative details rather than basic facts. My act, or state, of wanting, just *per se*, appears to have been the same in the two cases. To want an institution for the purpose of the satisfactions that knowing the Pacific Ocean and its living inhabitants might bring—wherein does the wanting *qua* wanting differ from wanting an orange for the purpose of the satisfactions that eating it might bring? As right now I ransack my memory in connection with the two series of experiences, it seems to me literally true that the half-hour series connected with the orange was in essence a fair epitome of the two-decade series connected with the Institution. That the decisions, the executive efforts, and the satisfactions and dissatisfactions differed quantitatively immeasurably in the two series is too obvious to need asserting. As to qualitative difference—well probably, there was some, especially in the matter of

satisfactions. There is, it seems to me, a difference between a physical satisfaction (nutritional for instance) and a psychical satisfaction (discovery of truth for instance), that is fundamentally qualitative. Perhaps the difference here involves the very essence of quality as does the difference between the different senses—sight and sound—for example.

But really what seems to me the deepest difference in the two series of experiences concerns satisfaction as contrasted with dissatisfaction. If my orange case had had in it (as it did not have) the element of obstacles to be met and entire or partial defeats to endure, as, of course, the Institution series had, the epitome of the latter by the former would have been more nearly exact. For instance had my wanting involved the getting of a whole meal instead of an orange; and had the getting of the meal depended largely on my own decisions and executive efforts, with my serious culinary limitations, the epitome would have been all that could reasonably be expected of an epitome. Nor would the case have been fundamentally different, so far as I can see, had what I wanted been a fortune, a woman's hand in marriage, the production of the greatest scientific discovery ever made, the greatest poem ever written, or the greatest social or governmental reform ever needed.

It will never do to let the views here expressed appear as though wholly isolable from certain other views. Of these "other views," particularly to be mentioned is that as to how wanting, the first member of the series, comes to be; and that as to how the actual acts, the last members of the series, accomplish the satisfaction at which the whole series aims. But while it would not do to leave this matter untouched, thus leaving the reader unaware (so far as this text is concerned) of its existence, the presentation of these "other views" would involve problems with which the present discussion is not concerned. It would be out of place here. And we must not permit anything to divert our attention from the main task in hand—that of discovering, if possible, how far the

interpretation that seemingly must be given *entelecheia* is applicable to man.

On the basis of a lifetime of conscious experiences of which the two here noticed are samples, and of the superposition upon these of much objective knowledge, I seem justified in defining what most authorities would call my Will as follows: *The word, "Will," is a highly generalized noun or name for what I, a living whole, cause my parts to do toward securing what I believe will be good for me.*

Such a definition is likely to strike many persons as too shockingly absurd to merit a minute's attention. Nevertheless, I submit it with confidence that after a while it will be recognized as meriting much attention. One thing that contributes to my confidence is purely historical. A glance at the index of any good work on the history of philosophy suffices to discover that a theory, or doctrine of some sort, of the will has been near the center of the chief systems of philosophy from Augustine to Nietzsche and Bergson.

Now I submit that no one half awake to the modern spirit of science and philosophy could presume for a minute that a theory of the will which did not involve a sound theory of mental life could be even approximately true or moderately useful.

Accordingly the treatment of the will by psychologists since psychology has claimed its independence of traditional philosophy and its alliance with the natural sciences seems highly significant.

To go into this subject as extensively as even I, a non-professional in either philosophy or psychology might go, would be unjustifiable. But a few specially relevant points can be easily indicated. On the evidence of the long chapter, "Will," in James' *The Principles of Psychology* we know that this psychologist had no misgivings (in theory at least) about the will's being a subdivision of the mind and thus a subject to be treated first and foremost by psychologists. This comes to particularly sharp expression in the essay, *Reflex Action and Theism*: "From its first dawn to its highest actual attainment, we find that the cognitive faculty, where it appears to exist at all, appears but as one element in an organic mental whole, and as a minister to higher mental powers—the powers of the will." (James, 1897, p. 140) This from James, the professional psychologist, when upon occasion he turned philosopher. Rather curiously, when upon occasion Royce, the professional philosopher, turned psychologist, he saw Will in a different light: "The word 'Will' is of little use," we read, "as a purely

psychological term, in the classification of mental life." (Royce, 1908, p. 334)

The main point of this, for us, is that, "Will" as Royce sees it, refers "to the whole significance of our conscious life" (italics original). This was one philosopher's way of saying that our decisions and actions are what they are because of our relation to our environment, or the world.

These views seem distinctly anticipatory of such other up-to-date views as that "Will is not precisely a psychological term, anyway, but is a term of common speech which need not refer to any psychological unit. (Woodworth, 1921, p. 523)

What looks to me like a more positive trend toward the conception of will I have formulated is the inclusion of it in a set of terms for "aspects of the total activity of the organism." (Gates, 1925, p. 463) And indicative of psychology's still further advance in this direction is the fact that some of the most up-to-the-minute schools appear to make no use whatever of the term "will." I venture to suggest that the farthest point yet reached by psychology on the road to such a conception of the activities of a living whole-and-its-parts as I am proposing, is the "behavior *qua* molar," set forth particularly by Tolman (1932).

It seems improbable that "molar" used thus would refer without important qualification to an individual animal (a man for instance) acting as a living corporeal whole. The molarity appears to connote mass as activity merely rather than mass as activity together with the acting body and all its parts. Nevertheless the conception comes so much nearer the true nature of living animals than does the conception of "behavior *qua* molecular" with which it is contrasted, that it may well be hailed by natural history as a great forward step for "pure psychology" to take.

We return for a moment now to the quotation from Gates about the activity of the organism. Shift the word "total" and make it modify "organism" instead of "activity" and the phrase would be readily interpretable in conformity with my definition of "will." For "total organism" would really have to mean, from the meaning of the whole phrase, what "living whole" means in my definition. Indeed there is little doubt that "total activity" of Gates's phrase implies the same thing. And in either case there would be implied, almost certainly, Aristotle's conception of *energeia* as applied to living beings, the actual organism acting as a whole. But it should be noted that the concept of *entelecheia* seems not to be implied.

Ridiculously brief is the sketch presented above of a human individual acting in two

particular cases, one at a rather low, the other at a rather high, level of his normal conscious existence. But I venture to hope the sketch may go far toward clarifying the conception that in both these cases or any other conceivable real case the individual, *whole*, that is to say, the individual consisting of all its parts acting in complete unification, was the main Factor, or Cause, or Principle—name it to suit yourself.

As a precaution against misunderstanding here I remark that the conclusion stated is not at all concerned with questions of relative excellence or greatness, or the reverse of these, of individuals. Rather, the concern is with the real nature of any and every typical human individual—with the question of what any and every typical human individual *really is*.

PROCREATION, SEXUAL PLEASURE, AND THE WHOLE-AND-ITS-PARTS

We pass now to a very different aspect of the central aim of this essay. That aim is, we never forget, the question of the relation of Aristotle's conception of "complete reality" (*entelecheia*) to the conception of a whole-and-its-parts as applied particularly to the human individual, the conception being viewed in the light of modern knowledge.

Mindful as we are of Aristotle's great respect for, and attention to, the phenomena of genesis, our previous notice of a favorite refrain of his about the begetting of men by men is convenient for connecting what we are now to present with what we presented earlier. It would be useless to try to understand Aristotle's attitude (as distinguished from his knowledge) relative to the problem of a man as a "complete reality" without considering his attitude (again as distinguished from his knowledge) *qua* man as a potential begetter of children.

In passing to this aspect of the subject we come upon defects in Aristotle's general system that are serious and by no means all pardonable, so far as I can see,

on the ground of meager factual knowledge. The defects are in considerable measure due either to deliberate neglect or to faulty reasoning. Hicks' reference to this is brief and explicit. We read: Aristotle "exalted the cognitive element, while his treatment of the emotions and the will is wholly inadequate, even if the *Ethics* and the *Rhetoric* be called in to redress the balance" (Hicks, 1907, Introduction, p. lxxii).

We focus on the defects that are particularly relevant to this discussion. Aristotle was not, of course, blind either as a man or as a scientist and philosopher to the emotions and passions of sex. We know this about him as a man from the biographic record of his marriage, his devotion to his wife, and his being a father. And we know he gave real attention to the subject as scientist and philosopher from various things in his writings. Take this example:

"Thus there is one single moving cause, the appetitive faculty. For, had there been two, intelligence [*nous*] and appetency, which moved to action, still they would have done so in virtue of some character common to both. But, as a matter of fact, intellect is not found to cause motion apart from the appetency. For rational wish is appetency: and, when anyone is moved in accordance with reason, he is also moved according to rational wish. But appetency may move a man in opposition to reason, for concupiscence is a species of appetency." (*De Anima* 433^b 2-5, Hicks trans.). Although the word, *epithymia*, here rendered concupiscence, does not mean sexual lust exclusively, this meaning along with others seems undoubtedly to have been part of Aristotle's meaning. Such discussions as that on continence and incontinence in Book VII of the *Nicomachean Ethics* leave no room for question on the point.

Yet curiously enough in the elaborate and on the whole movingly admirable discussions of "Love or Friendship" and of "Pleasure" in the *Ethics*, we find scarcely a hint of the amorous element in the relation between a man and a woman! It is hard to see that there was any ground for Aristotle's formal teachings about women (about their being impotent men, being

classifiable with children and slaves and so on) other than the prevalent teachings of his age and country.

Really were it not for what the man gives us when he speaks as an unsophisticated zoologist, we might suppose he was too much of a Puritan or highbrow or something to discuss or even think much on the most domineering aspect of sex life.

After this was written I was glad to have my attention called to the fact that a few professional ethicists of today refuse to accept the traditional separation of reason and feeling. For example we read: "By enjoyment' we are meaning all the while a mental fact, conscious appropriation." (Fite, 1925, p. 212.)

Fortunately, some of the things Aristotle says in the zoological works are sufficiently specific and are significant for our problem since they touch upon the climax of the sexual emotion. As would be expected, the most important of these are in *The Generation of Animals*. In his devastating criticisms of the theory attributed to Hippocrates that the semen comes from all parts of the body, the first of the four arguments in support of this Aristotle says is: "First, the intensity of the pleasure of coition; for the same state of feeling is more pleasant if multiplied, and that which affects all the parts is multiplied as compared with that which affects only one or a few." (*De Gen.* 721^b 15, Platt trans.). What specially concerns us is the explanation offered of the pleasure of copulation. Aristotle's reasoning against the theory proposed as to the source of the semen, important as it is, concerns us only indirectly now. That aspect of the problem we noticed sufficiently in the first part of this essay.

Obvious, is it not, that the explanation proposed of the extent of the pleasure would tally very well with the conception we are defending of the whole-and-its-parts? What, if anything, then, we naturally ask, has Aristotle to say touching this aspect of the problem? Unfortunately what he

says is brief and only inferential. Yet the inference seems unescapable. "As to the vehemence of the pleasure in sexual intercourse," we read, "it is not because the semen comes from all the body, but because there is a strong friction (wherefore if this intercourse is often repeated the pleasure is diminished in the persons concerned)." (*De Gen.* 723^b 35)

Clear enough, then, is the recognition that the pleasure needs a causal explanation of some sort. So here it is: "And as to the pleasure which accompanies coition, it is due to emission not only of semen but also of a spiritus, the coming together of which precedes the emission." (*De Gen.* 728^a 10)

There you have it! *Pneuma*, that which imagination may make of the air essential to life, of the Zephyrs that stir the leaves, and of the tempests that lash great bodies of water into fury. What an amazing convenience for sophisticated thinking in the absence of factual knowledge!

Our only interest (except historic) in it is as to how the human organism would have to be involved to make the theory of sexual pleasure held by Aristotle consistent with his factual and theoretical knowledge as a whole.

The wording of the last quotation does not indicate that the author conceived the pleasure to be due to the involvement of the whole body with the spiritus. But even so when we have to do with such uncertainty as that of how *pneuma* transforms into spiritus, vagueness even to vagary of almost any sort, may be expected.

ARISTOTLE'S THEORY OF REASON AND OF PLEASURE IRRECONCILABLE WITH ENTELECHEIA

The question of how *pneuma* as he conceived it on the whole, we might examine at any length. But the futility of doing so, however well the task might be done,

is apparent once we remember that we are not much concerned with Aristotle's conceptions and teachings, *per se*. Our concern is with their validity as tested by modern knowledge. For such testing Aristotle has himself prepared the ground in this case.

His recognition that there is no sharp dividing line between reason and emotion we have already noticed. "Intellect," we have heard him say, "is not found to cause motion apart from appetency. For rational wish is appetency; and, when anyone is moved in accordance with reason, he is also moved according to rational wish. But appetency may move a man in opposition to reason, for concupiscence is a species of appetency." Put this from the *De Anima*, a biological treatise dealing primarily with mental phenomena, alongside the quotation given above from the *De Generatoine*, a treatise dealing primarily with reproductive phenomena, and notice what you have. The vital and familiar truth is presented in a somewhat round-about way that however exaltedly endowed with reason man may be he is yet driven at times with sexual desire.

So Aristotle almost forces us to ask whether the whole man as thus clearly indicated corresponds with his own more fully elaborated conception of man. Another, and for this discussion, more relevant way of asking the same question is: Is Aristotle's conception of man as unmistakably indicated in his zoological works (the *De Generatoine* and the *De Anima* particularly) the same, fundamentally, as that presented in his philosophical works (the *Ethics* and the *Metaphysics* particularly)? Finally, and still more to the point, we may ask the question thus: Is Aristotle's term *entelecheia* applicable to man as his conception of man stands in its most philosophical (metaphysical?) form?

Categorical answers to the last two forms

of the question I believe must be: (1) Aristotle's conception of man contained in his traditionally philosophical works is irreconcilable in several ways with that contained in his traditionally biological works; (2) Not only is his concept of "Complete reality" (*entelecheia*) inapplicable to his philosophical (metaphysical) conception of man, but he himself probably felt this as he seems not to have applied the term at certain crucial points in his "first philosophy" of man.

A justification if possible of these answers is manifestly due from me. The problem is necessarily involved in Aristotle's general theory of the psyche, or soul. So well known is his teaching concerning the separateness or at least separableness of reason, or the rational part of the soul, from the body that extensive treatment of the subject may be disposed of very briefly.

The following may be considered to present the kernel of his teaching on this great subject:

Turning now to the part of the soul with which the soul knows and thinks (whether this is separable from others in definition only, or spatially as well) we have to inquire (1) what differentiates this part, and (2) how thinking can take place.

If thinking is like perceiving, it must be either a process in which the soul is acted upon by what is capable of being thought, or a process different from but analogous to that. The thinking part of the soul must therefore be, while impassible, capable of receiving the form of an object; that is, must be potentially identical in character with its object without being the object. Mind must be related to what is thinkable, as sense is to what is sensible.

Therefore, since everything is a possible object of thought, mind in order, as Anaxagoras says, to dominate, that is, to know, must be pure from all mixture; for the co-presence of what is alien to its nature is a hindrance and a block: it follows that it too, like the sensitive part, can have no nature of its own, other than that of having a certain capacity. Thus that in the soul which is called mind (by mind I mean that whereby the soul thinks and judges) is, before it thinks, not actually any real thing. For this reason it cannot reasonably be regarded as blended with the

body: if so, it would acquire some quality, e.g., warmth or cold, or even have an organ like the sensitive faculty: as it is, it has none. It was a good idea to call the soul "the place of forms," though (1) this description holds only for the intellective soul, and (2) even this is the forms only potentially, not actually (*De Anima* 429^a 10-28, Smith Trans.).

Probably no reader will need reminding that modern knowledge of the functions of the brain leaves the statement that thinking has no organ without a trace of fact to rest on. Nor will many readers fail to recognize in the statement about the soul as the "place of forms" one instance of Aristotle's seeming adherence to Plato's doctrine of Ideas.

Still more pointed about reason's independence is: "While the faculty of sensation is dependent upon the body, mind is separable from it." (429^b 4)

As a revealer of what Aristotle knew and what he did not know about the psychobiology of man, and of his reasoning on the subject, these are crucial passages. The striking deficiency in his knowledge was of course anatomical and physiological: He knew nothing of the fact that brain is indispensable to thought. One might make considerable of the fact that in his comparison of perceiving with thinking Aristotle varies his language somewhat. While sensation is "dependent" on the body, mind is "separable" from it. Does this suggest that after all he had some misgivings about the complete lack of dependence of thinking on the body? May he not have surmised that as to its *origin* mind has some kind of dependence on the body while in its *functional* maturity it may not be thus dependent? Might not the mind's dependence on the body be something like an apple's dependence on the tree—dependent for origin but not for later existence and function? With all Aristotle knew about the generation and nutrition of animals and other living things it seems incredible that he should not have had some qualms about the separableness of reason from the body. So extensively and insistently does he present his conception of the nutritive and sensitive parts of the soul that I assume my readers sufficiently acquainted with this phase of the matter to obviate the need of going into it further. It will be enough, I hope, to assert and nothing more, that he never even suggests that these two parts of the soul are separable from the body. The rational, the thinking, part only be conceived to be separable. But how

could he make this tally with what he knew and tells us so distinctly (as quoted above) about the way reason and appetency are tied up together?

But what specially concerns us is the bearing of Aristotle's belief in the separableness of mind from body on his conception of *entelecheia*. Can we get any light on this matter from studying the passages on separableness quoted above? They contain three points that are illuminating in this way.

The first is contained in the inquiry about the separableness of the soul. If we turn from the Smith translation (used in our quotation) to the translation used by Ross in his *Selections*, we find a difference that appears significant to a morphological biologist. The wording in the Ross version is: "With regard to the part of the soul by which it knows and thinks, whether this be separable or not separable in spatial magnitude but only in definition," etc. The point at issue is between the "spatially as well" of the separableness in the Smith translation and the "spatial magnitude" of the separableness in the Ross translation. *Megethos* is the term in the original which is rendered "spatially" in the Smith version, and "spatial magnitude" in the Ross version. Now since *megethos* means bulk or size, and hence implies shape, it is considerably more positive as to corporeality than is "spatially." This distinction is particularly significant because space has no objective reality for extreme idealistic philosophers, and appears to be in somewhat the same predicament at the hands of some present-day mathematical physicists. Viewed in this light the query is pertinent: Was not Aristotle virtually asking whether the thinking part of the soul *together with a part of the body* is separable from the rest of the body? This would seem in accord with his usual naturalistic attitude. So no wonder the man was puzzled—as we

know he was from passages like this: "Hence arises a question of the greatest difficulty, which we must strive to solve to the best of our ability and as far as possible. When and how and whence is a share in reason acquired by those animals that participate in this principle?" (*De Gen.* 736^b 5).

The second point to be noticed touches the question from a different angle. Following the statement about the necessity for the mind's purity from admixture we read: ". . . it [mind] too, like the sensitive part, can have no nature of its own, other than that of having a certain capacity."

That the thinking and the sensitive parts of the soul can "have no nature" of their own other than a certain capacity, or potentiality, is surely at odds with our modern knowledge of capacity, as we have seen in previous discussions. Nothing has just capacity alone. It is besides an entity in its own self. Explosives, for instance, and seeds, have natures of their own in addition to their capacities as explosives and as producers of full-fledged plants. So this makes it impossible to accept the statement as a valid argument.

But the weightier reason for calling attention to the point here is that it is not fully consistent with Aristotle's own general attitude toward nature, nor with some of his specific statements. Thus his repeatedly expressed view that a thing's nature consists in its matter, or substance, and its form, or final actualization, and also in the movements or changes by which it passes from one to the other, is entirely consistent with our present knowledge, but not with such a view as that here expressed. Take for instance his final, summed-up statement about nature in the chapter devoted to that subject in the lexical book of the *Metaphysics*:

From what has been said, then, it is plain that nature in the primary and strict sense is the essence of things which have in themselves, as such, a source of movement; for the matter is called the nature because it is qualified to receive this, and processes of becoming and growing are called nature because they are movements proceeding from this. And nature in this sense is the source of the movement of natural objects, being present in them somehow, either potentially or actually. (1015^a 10-15, Ross trans.).

As a general statement this would seem to cover satisfactorily present-day information concerning the brain as an organ of thought.

The "somehow, either potentially or actually" of the fact that thought is present as a "natural object" in the brain would probably be satisfactory as a general statement to modern neurologists.

The third point which we notice involves directly the question about the bearing of the statements under examination on the problem of *entelecheia*. The essence of the point is in the statement (supposedly referring to Plato) about the soul's being "the place of forms." Directly following this, Aristotle adds his own limitation upon it: "though (1) this description holds only of the intellectual soul, and (2) even this is the forms only potentially, not actually." The crux of the matter is that *entelecheia* is the term rendered "actually" in the translation. The original phrase is worth quoting: οὐτε ἐντελεχεία ἀλλὰ δυνάμει τὰ εἶδη. "Not *entelecheia*, however, but *dynamis* is [the form or idea]." That is to say, the intellectual soul being unmixed with body does not come under the concept of *entelecheia* because *entelecheia* includes both potentiality (*dynamis*) and actuality (*energeia*). In other words on the basis of what we are here given, it appears that Aristotle recognized that in conceiving the intellectual part of the soul as separable from the body, he was placing it outside his concept of *entelecheia*.

Thus we have at the highest level of man's nature what is seemingly another piece of evidence that in Aristotle's real purpose *entelecheia* was fundamentally a descriptive term for his natural science and hence was excluded from the highest flights, so to speak, of his "first philosophy." And are we not justified in concluding that the crucial statements under examination contain irreconcilable if not contradictory views and that these are largely if not wholly traceable to the author's complete ignorance of the functions of the brain and nervous system?

While such a conclusion does not constitute final proof that had Aristotle known the function of the brain, of the cerebral cortex especially, he would not have believed in the separableness of the intellective part of the soul, it does show that he had advanced so far toward a wholeness, or unified theory of man that he could not depart from his general direction without contradicting himself. This reference to the idea that *entelecheia* would be applicable to man in the whole gamut of his individual life only by including its potentialities as well as its actualities (which, note, it does not include according to the statement under examination), is a point at which we may conveniently resume the examination of Aristotle's teaching concerning the appetative faculty of the soul as this manifests itself in the sexual mode of reproduction. This resumption is necessary to enable us to see still further what appears to be implied concerning a human being's wholeness in his teaching about sexual pleasure.

RELATION BETWEEN PLEASURE AND SENSATION—ANCIENT AND MODERN VIEWS

In resuming this examination we note first Aristotle's conception of pleasure. The phase of the conception that is spe-

cially relevant to the point in hand is stated, more or less clearly in various connections, perhaps nowhere more so than in the following: "Where there is sensation, there is also pleasure and pain, and, where these, necessarily also desire" (*De An.* 413^b 20. Smith trans.). The main point here is that sensation is always accompanied by pleasure or pain. And this clearly means (from what we have already learned) that the sensitive soul at least is always experiencing pleasure or pain. Satisfaction or dissatisfaction would probably come nearer to Aristotle's meaning. What immediately follows the passage just quoted, though bearing only indirectly on the main point, is important: "We have no evidence as yet about mind or the power to think; it seems to be a widely different kind of soul, differing as what is eternal from what is perishable; it alone is capable of existence in isolation from all other psychic powers." For us the most significant thing about this passage is the unmistakable evidence it furnishes of Aristotle's uncertainty as to whether the intellective part of the soul is or is not linked with the other parts—the nutritive, sensitive, and locomotive parts.

In the light of what the anatomy, histology, and physiology of the neuromuscular system and especially of the cerebral cortex, have taught us, Aristotle's uncertainty about the connection of the "mind or power to think," with sensation is only of antiquarian interest.

But what about the relation of sensation to pleasure and pain? Do we know for a certainty that "where there is sensation there is also pleasure and pain?" Still more, do we know that where there is pleasure or pain there is also sensation?

I fail to find anything in any of the works that seems to be an effort at a *direct* answer to these questions. But it matters little whether Aristotle made such an

effort or not, for we are sure he could not have made much real headway in it. The whole factual realm most directly involved is that of the minute structure and function of the sensory and motor nerve terminals, the details of stimulus and response, and so on.

But I believe that if we study his utterances about pleasure in the various works, particularly the long discussion of it in the *Nicomachean Ethics*, beginning the study with what he gives in the *History of Animals*, we may recognize that he laid the foundation for a conception of pleasure upon which a sound modern conception can be erected. The passage in the *History* specially referred to is:

The life of animals, then, may be divided into two acts—procreation and feeding; for on these two acts all their interests and life concentrate. Their food depends chiefly on the substances of which they are severally constituted; for the source of their growth in all cases will be this substance. And whatsoever is in conformity with nature is pleasant, and all animals pursue pleasure in keeping with their nature. (589^a 5, Thompson trans.).

A student approaching Aristotle in the more usual way, namely, from the side of formal philosophy, is likely to question whether in such a statement the author really includes man with animals. Does he in very truth mean, for instance, that all man's "interests and life concentrate" on "procreation and feeding?"

We know well, from the *Ethics* particularly, that Aristotle was about as far as any philosopher or religionist, or any humanist of whatever school ever was, from viewing man as a "beast of the field" in the degradative sense often attached to that phrase. But from the context of this passage, it is impossible to avoid (if we wanted to) recognizing that man was here included in Aristotle's thinking as definitely and certainly as was any other animal. The passage is in the eighth book

of the *History*, which may, I think, be fairly regarded as near the high-water mark of Aristotle's writing on natural history. For instance, his statement about nature's proceeding "little by little from things lifeless to animal life," that has become famous from being interpreted as adumbrative of the modern theory of Evolution, occurs in this book. But the opening sentence of the real discussion of the book tells us in so many words where the writer stands in the treatment.

In the great majority of animals there are traces of psychical qualities or attitudes, which qualities are more markedly differentiated in the case of human beings. For just as we pointed out resemblances in the physical organs, so in a number of animals we observe gentleness or fierceness, mildness or cross temper, courage or timidity, fear or confidence, high spirit or low cunning, and, with regard to intelligence, something equivalent to sagacity. Some of these qualities in man, as compared with the corresponding qualities in animals, differ only quantitatively: that is to say, a man has more or less of this quality, and an animal has more or less of some other; other qualities in man are represented by analogous and not identical qualities: for instance, just as in man we find knowledge, wisdom, and sagacity, so in certain animals there exists some other natural potentiality akin to these. (*Historia*, 588^a 20-25.)

The unqualified animalness of man, though of a kind that is enormously high, relatively, in Aristotle's thinking, especially when he was at his best as a naturalist, does not, we hope, need further illustration.

Now can there be any other interpretation of the sentences quoted than that Aristotle conceived pleasure to go along with sensation to the very root-tips of animal life and so of the life of individual man? What else can be made of the statement that all animals seek pleasure "in keeping with their nature?" The real question here is as to the lower limit of sensation. So far as Aristotle's means of testing could go, he was probably justified in considering plants devoid of sensation.

In other words he was probably justified in considering sensation a strictly animal attribute.

Essentially the same idea is variously expressed by Aristotle. Thus: "Each kind of being, again, seems to have its proper pleasure, as it has its proper function,—viz., the pleasure which accompanies the exercise of its faculties or the realization of its nature." (*Nicom. Eth.* Book X, 5, 8. Peters trans.)

This identification of pleasure with the fundamental nature of living beings is so important for two hypotheses I am being led to, that we must consider its historic and factual backgrounds a little farther. Such consideration is needed in our day especially, perhaps, because of the wide currency of quite different interpretations and valuations of pleasure.

That Theophrastus, a pupil and disciple of Aristotle, should have had a similar view of pleasure is not surprising. "For Theophrastus," we read, "pleasure is the normal accompaniment of what is in accord with nature. As a rule, therefore, we take *pleasure* in things, since the common course of our functions is inevitably 'natural' and not antagonistic to nature" (Stratton, G. M., 1917, p. 48). And one passage from Theophrastus himself is much to the point because it is in refutation of a view of Anaxagoras which fits well with a brand of cynical philosophy quite prevalent in our era. "But as for the thesis," says Theophrastus, "that sense perception is universally conjoined with pain, this finds no warrant in experience, inasmuch as some objects are actually perceived with pleasure, and most of them at least without pain." (Stratton, p. 93). Those of our contemporaries who have been educated into a spiritual condition such that in whatever they do toward enjoying themselves they appear to get more misery than pleasure from it, will not of course be impressed by either the conception of pleasure that comes to us from Aristotle and Theophrastus, nor by a like conception from modern sources.

It is, however, important to note that many persons of this very day whose voices can hardly be ignored, have reached quite similar conceptions. A few of the many available references must suffice. "Simply to live, move and breathe, should be a delight." This statement by William James, is entitled to the more respect, I submit, from being quoted with approval by a foremost physician and contemporary worker in public health (Winslow, C. E. A., 1924, p. 214).

The only other statements I give space to are chosen

for the trustworthiness of the authority, and, more especially, for the approach (as it seems to me) of the views expressed to the hypothesis to which we are coming.

We read: "Pleasantness might represent a general *organic state*, and unpleasantness the contrary state, each state being an internal bodily response to pleasant or unpleasant stimuli, and making itself felt as an unanalyzable compound of vague internal sensations." Again: "Pleasantness and unpleasantness are much less definitely localized [than sensations from the special senses]; they seem to be 'in us' without being in any special part of us." (Woodworth, 1921, pp. 175 and 174.)

What, we must now ask, do these diverse references to sensation and what is pleasant or unpleasant point toward? The literally immeasurable extent to which personal experience and common observation find sensation, feeling, emotion, passion and the rest, dependent on stimulations, external and internal, inevitably suggests that in seeking an answer to the question, the quarter to be turned toward first should be that of the most searching investigation yet made, on the dependence of the phenomena of living bodies on the responsiveness of the bodies to stimulations as just indicated. And thus we run head-on into one of the most recondite and also far-reaching divisions of psychobiology. It would be futile to attempt an exhaustive exploration of this realm here. But it would be equally futile to try to understand the issues most fundamentally involved without having got a firm hold on the main results of researches in the realm. So we must do our best under the circumstances toward such a hold.

Conformably with the historic diathesis of our enterprise we may first notice Aristotle's very wrong supposition that plants are devoid of sensation. The question of whether he did or did not produce a treatise on plants and the further question of whether, if he did, he could have still held to his error in this matter, it is useless to speculate on. For the error he certainly made and it appears to have influenced, willy-nilly, his whole theory of the activities of living beings.

Possibly, however, he was not quite so wrong as to facts nor unjustifiable as to theory as he seems. For in one passage at least he goes some distance toward recognizing the truth. After referring to the fact that various mechanisms may be injured or destroyed by being driven too hard in the performance of their normal function, he tells us: "This explains also why plants cannot perceive, in spite of their having a portion of soul in them and obviously being affected by tangible objects themselves; for undoubtedly their temperature can be lowered or raised." (*De An.* 424^a

30 Smith trans.) It has been suggested that in the distinction here made between perceiving and being affected, Aristotle was aiming at an old and fanciful notion about feeling of joy and sadness experienced by plants.

The merest reference to what everybody knows about the *Mimosas* and other "sensitive plants;" about insect catching and devouring plants; and about the action of twining and tendril clinging plants, will suffice as familiar evidence of Aristotle's general wrongness in this matter.

Turning to the less familiar data, a summary statement may be made as follows: Some of the most exact and illuminating researches of the modern period into the "irritability," the "excitability," the "stimulability" (various terms meaning much the same thing) of living organisms, have been conducted on plants, nearly the whole range of the plant world having been requisitioned for investigative materials.

As a hint at what recent history presents in this realm, the work of the botanist Pfeffer may be mentioned. The choice falls here largely because this investigator's handbook is widely and favorably known.

In an interesting section of the book, entitled "nature of irritability," we read: "until recently the part played by stimuli in all vital phenomena has been overlooked." (Pfeffer, 1900, p. 13.) The date (1880) of the first German edition of this work indicates the extreme recency of scientific knowledge in this field. As the quotation clearly implies, when irritability at its base level is under consideration, there is no fundamental distinction between plants and animals. And since plants have no sense organs as this expression is usually understood, their sensitivity must depend on a very general property of living beings. So it happens that in the writings of the period of Pfeffer and a little earlier, one constantly finds statements to the effect that sensitivity, or responsiveness to stimuli, is a property common to all "living matter" or protoplasm. More recently results coming from increasingly refined investigation, the conception of sensitivity as a general property of "living matter" has had to be modified to the extent of recognizing that this general property belongs to living matter only as such matter occurs in organized, living bodies. Otherwise expressed, the concepts of both aliveness and sensitivity seem to be inseparable from the concepts of body and organization. The concept of "living matter," or "protoplasm" as a universal, undifferentiated, unorganized, uncorporealized something or other now stands in opposition to an enormous mass of observational knowledge, and is unsupported by a scintilla of such knowledge. The great science of living cells,

cytology, is manifestly opposed to the concept. But cells are by no means the bottom link, so to say, of the chain of observational data opposed to the concept. In truth, cytological knowledge as now being developed, is concerned largely with a host of bodies of various sizes and shapes and degrees of permanence within cells. Although many, probably most, of these are not alive in the full sense, their undoubted contribution in one way or another to the vital activities of the cells is entirely at one with the conception of organized corporeality as a *sine qua non* to aliveness. "Living matter" has, in both fact and logic, about the same status that the term "humanity" has. There is no more justification in imagining "living matter" as something apart from and antecedent to living bodies than there is in imagining "humanity" as something apart from and antecedent to, human beings.

"Protoplasmic systems" is a term now much used by investigators occupied chiefly with the functional, or physiological side of vital phenomena at these foundational levels. What the parts are and that the organization is, of these deep-level bodies, though of great interest, especially to experimental workers, can be merely touched here. Reference must be made to the great rôle the surfaces of the bodies play in the phenomena presented. "Surface layers" and "limiting membranes" are basic in the terminology of knowledge here. Now this character of these bodies lends itself well to the seeming necessity of extending our conception of sensitivity from our common experience as bodies to these deep-level bodies.

And we must notice that Aristotle, starting from this same common experience and applying to it principles of reasoning he himself had worked out, reached conclusions that are in striking general accord with the results of late experimental research. Thus on the problem of a living body and the matter of which it is composed, we read: "Now there is one class of existent things which we call substance [*ousia*], including under the term, firstly, matter [*hyle*], which in itself is not this or that; secondly, shape or form, in virtue of which the term this or that is at once applied; thirdly, the whole made up of matter and form." (*De An.* 412^a 2 Hicks trans.). Highly important is it that "shape or form" here is the crass thing of modern morphology. *Morphe kai eidos* is the original. That which is observed as well as the idea of it is what we have to do with. When we reflect that in the discussion of which this paragraph is a part Aristotle is dealing with the problem of the relation of the soul to the body; and note that the question of the "sensitive and appetitive faculties" was always conspicuously in his thought, we may well be impressed by the closeness of his approach, so far as theory is concerned, to the modern position.

There is now an enormous mass of evidence in court on the rôle of stimuli, excitators, activators in vital phenomena. This evidence makes it look as though we shall have to recognize that such phenomena are as dependent on externality for excitation to action as they are for building materials, and energy-yielding materials for action. But, of course, "externality" as thus used would include all such facts as that any part of our bodies, our kidneys, or gonads, or blood corpuscles, or cells generally, are external to all other parts. The conception of vital spontaneity, or automisity in a strict sense, in the sense, that is, of ability of a living body of any kind or grade either to begin its acts or to modify them, just by its own exclusive self, appears to be on the verge of elimination from sound biology. The following seems a fair epitome of conclusions under this head:

"As the facts stand at present there is no reason for assuming the occurrence of self-excitation. Spontaneity in a strict sense is far from being a demonstrated fact. One cell region, cell or cell group may of course excite another, but the original source of excitation and of the initiating energy is apparently always outside the region, cell or cell group excited." (Child, 1924, p. 186.)

What the relation of non-spontaneity as here indicated may be to the spontaneous, or autonomic atomic activity now receiving much attention by physicists, is an important but seemingly a very difficult question. The surmise that the doctrine of electronic indeterminism lends physical support to the doctrine of "free will" is easy to make, and seems congenial to certain types of feeling and thinking. And there may well be a connection of some recondit kind between the two. If men could discover scientific backing for an hypothesis that they are free to act in some such way as radio-active substances are, the discovery would be significant in several ways.

But it is important not to forget that the first mentioned doctrine is strictly atomistic-mathematical while the second is far from that. The "free will" is crasslymolar, i.e., corporeal, so far as all experience in exercising it goes. But still more important is it not to forget that both doctrines are items in, are products of, the knowledge-getting activities of human

beings. The doctrine of atomic indeterminism is utterly dependent on *facts* that are molar or corporeal. These facts are, for one thing, the utter dependence of human observing, knowing and thinking on being humanly alive; and further the utter dependence of being alive on breathing, eating and the rest. Now these facts are so familiar as to tend to become just taken for granted. And things just taken for granted are, if highly complex, always liable to be treated as though some of their elements just do not exist.

Lillie has recently published some highly interesting discussions in this general field approached from the side of modern physiology (Lillie, 1931 and 1932).

"PLEASURE-PAIN" IN RELATION TO THE WHOLE-AND-ITS-PARTS

What, now, is the bearing of all this on the problem of pleasure? My answer is the first of the two hypotheses forecast several pages back. *Our experiences which we characterize as pleasant, agreeable, satisfying, and to which we give such names as pleasure, happiness, joy, are rooted finally in our sensitivity as bodies that are alive.* Their foundations are laid at the moment of our conception, are much advanced by being born, and are never entirely absent as long as we live. This deep-level truth gets partial recognition in the familiar statement, "Self-preservation is the first law of life." From the exercise by every living body of its ability to maintain itself we get such concepts and sayings as that it is "good to be alive." Of prime importance is the recognition of that double dependence on externality (in part the "external world" of common experience) which our discussion focused attention upon. Each living body depends on what is external to it for its building and energy-yielding materials (air, food, water), and also for stimulation to all its activities. A body is alive in and of its ability to *use* for its own existence a relatively few things external to it, and to *respond to*, and *sense*, a literally uncountable number of things external to it. For a body to exercise these abilities is to fulfil, or to satisfy, its nature. These are the

very bottom acts by which a living body "makes good." This is as fundamentally true for the meanest weed-seed that in response to moisture and warmth pushes its sprout through the hard ground, as for the greatest human genius that responds to conditions of his time and surroundings and to his own internal "urge." Sensitivity and responsiveness as here touched upon, are basic to the concept of life-or-death needs and activities, and life-fulfilling needs and activities suggested elsewhere (Ritter and Bailey, 1927, pp. 268 and 295).

This tracing of the roots of goodness, the "good life," the "it is good to be alive," to their tips in the very deepest level of aliveness of animate bodies is likely to shock those who still cling to the teachings of traditional philosophy and ethics on this matter. For our interpretation gives no quarter to the idea of an ultimate, incarnate Good, that always, since Plato, has figured in one form or another in the theories of many delvers into the problems of human life. That is good according to this interpretation, which is intrinsic and essential to the very nature of the living being and is no outsider, or alien, even though its dependence on externality is irremovable. Goodness does not just come, somehow, from some imagined where, to occupy a portion (the spiritual or mental portion) of that relatively small group of living beings called human by us of the western world. "Good" though as deeply real as life itself, is not of extra- and supra-mundane origin in an imaginary Divinity. Rather, it is basic quality, or sense, inherent in, and essential to, the state of aliveness. Divine goodness is derived by abstraction from it; not it from Divinity.

(This is no treatise on the problem of Good and Evil. Since, however, we are led by the nature of this enterprise to touch the "good" aspect of the problem, I can not consistently leave the other, the "evil," aspect wholly untouched.

If my interpretation of "good" is right, it seems obvious that "evil" is not an antithesis of it in the sense that, for instance, white is the antithesis of black, or warm of cold. The existence of "good" is not conditioned on the existence of "evil" as its essential contrast. The antithesis of "good," is "dead," dead implying something that was alive but died. The "good" of a living being might, theoretically, experience little evil or even none at all.)

Now is there reasonable doubt that what we have here said is only a revision and extension in the light of present-day knowledge, of Aristotle's "where there

is sensation, there is also pleasure;" of James' "simply to live, move and breathe should be a delight;" and Woodworth's "pleasure is 'in us' without being in any special part of us?"

From what we have already learned of Aristotle's inability, partly from lack of factual knowledge, to see how nutrition, sensation, and reason could be interdependent and inseparable parts of that particular complete reality which is a man, we readily foresee that he would be unable to go the whole way with moderns in interpreting the good. It is, however, to the point to notice that he recognized both the fallacy and the practical inadequacy of the "Universal Good" as conceived by Plato.

(It is worth while, historically, to recall that one of the most memorable of Aristotle's direct references to his disagreement with Plato is in this very connection. It is here that he tells us: "such an inquiry is not a pleasant task in view of our friendship for the authors of the doctrine of ideas." But further: "in the interests of truth, we ought to sacrifice even what is nearest to us, especially as we call ourselves Philosophers." (*Nich. Ethics*, I, 8 Peters trans.)).

Full of positive interest though Aristotle's discussion of the good, happiness, and the rest is as it comes to us in the *Ethics*, it would be out of place to pursue it here. One minor point, however, has considerable bearing on our interpretation. That is, the numerous passages that reveal his doubts about the relation between reason and the various feelings and emotions. One illustration must suffice. Although he sets it down positively enough, that as to man "mere nutrition and growth" must be excluded, elsewhere we read: "Good, then, is not a term that is applied to all these things alike in the same sense or with reference to one common idea or form. But how then do these things come to be called good? for they do not appear to have received the same name by chance merely." Then, of special interest comes the answer: "Perhaps it is because they all proceed from one source, or all conduce to one end." (*Ethics* I, 6). I am quite sure that "one source" and "one end" of this conditioned statement could without forced interpretation include the lowest level sensations in the one direction, and the highest welfare of the organism in the other, of our interpretation.

(I venture to remind the reader in connection with this suggestion of Aristotle's about source and end relative to what is good, or my account on earlier pages of my own experiences in orange-eating and institution-building.)

Like in purport to the above, but more definite is Aristotle's recognition that the good for man must be connected with his "purpose in life," as we say. "Man's good," says Aristotle "would seem to lie in his

function, if he has one. But can we suppose that while a carpenter and a cobbler has a function and a business of his own, man has no business and no function assigned him by nature? Nay, surely as his several members, eye and hand and foot, plainly have each his own function, so we must suppose that man also has some function over and above all these." (*Eth. I, 7, 11.*)

The "function over and above all these" is, as all familiar with Aristotle's supreme appraisal of contemplation would foresee, the "life of his [man's] rational nature." Whether he was right in this is, of course, not our concern here.

This rather long but far from exhaustive examination of Aristotle's admirable even though fragmentary knowledge of the truth about sensation, pleasure, the good, and happiness has seemed indispensable to the prosecution of our main purpose in this division of our inquiry concerning *entelecheia*.

We now return to the reason for this diversion. The reason was, it will be recalled, what we found Aristotle saying about sexual pleasure when he was at his best as a zoologist but ignoring almost entirely when he was an ethicist. And we need to recall still more definitely what made this matter seem important. It was his guess, perhaps taken from Hippocrates, that the *intensity of the pleasure of coition is due to the involvement of the whole organism in the action*.

I wish to contend now that the revision of this guess in the light of modern knowledge as sketched in the foregoing discussion justifies the erection of the guess into a definite hypothesis, or perhaps more exactly, a definite theory; and further that if the theory is true, this aspect of sex constitutes one of the strongest manifestations of the wholeness in the sense of complete reality (*entelecheia*) of higher animal organisms. For notice the facts involved:

(1) The activity of copulation is linked with that of nutrition, in the two most basic of all vital phenomena for man and the vast majority of organic species. Those phenomena are of course, the maintenance of the individual and of the species.

(2) The excitation upon which the activ-

ity primarily depends is the most basic of all, namely that of physical contact, or touch.

(3) In accordance with the conceptions of excitation and sensitivity apparently necessitated by modern physiology, the sensation accompanying the activity reaches down to the same level of vital phenomena as do nutrition and metabolism. In other words, it reaches to every cell or part of a cell of the organism that is truly alive. That is to say, it reaches down to the simplest living units into which living bodies are resolvable.

Does it not follow, then, that if "good" as applied to living bodies means what numerous students have somewhat vaguely interpreted it to mean, and we have more definitely so interpreted it, that the Hippocratic-Aristotelian notion of the multiplication of the "good," the pleasurable, feeling, with the multiplication of the body parts involved, would be logically sound? But notice what one of the most fundamental improvements of this ancient theory affected by modern research, is essentially. Aristotle went far enough, we have seen, with such improvement to see that the intensity of the pleasure could not be due to the coming of the germinal material from all parts of the body. But remember his substitute—*pneuma*, spiritus!

It seems to me a fair question whether Aristotle does not come nearer (perhaps unwittingly) a unitary theory of the soul, and of soul and body, in connection with this very matter of sexual pleasure than in any other whatever. The question hinges on the rôle ascribed to the spiritus in coition and the views previously noticed that "intellect [nous] is not found to cause motion apart from appetency." Still more definitely in this direction, recall the recognition that concupiscence, a kind of appetency, "may move a man in opposition to reason."

So we are led to conclude that the wholeness of an organism manifested in the ecstasy of sexual intercourse as this is experienced by man and the higher animals generally, is one of the most characteristic and powerful items in the complete reality of these organisms. The momentarily complete monopoly of consciousness at the climax of sexual ecstasy should probably be viewed as the very highest manifestation of the individual's conscious unifiedness and wholeness. But it is important to notice that the tendency of the emotions to such monopoly is not by any means restricted to the erotic emotion. Many forms of contest, for instance, both physical and mental, may go far in this direction. In all such cases there is ample evidence not only as common experience, but from scientific research, of the involvement of very many, if not all, parts of the organism.

EVERYTHING WHATEVER AND THE WHOLE-AND-ITS-PARTS

Finally we must face the supreme question of all: What did Aristotle do about his conception of *entelecheia* when he viewed it in connection with his conception of Everything that Is or Has Been or Will Be? For we may be sure, from what we have abundantly learned about the man that he was not of the kind either to fail to ask this question or to do something toward answering it. Naïve and philosophical naturalism (Ritter and Bailey, 1927, p. 7) were altogether too closely intermingled in him to permit him to overlook or shy at the question.

Almost the most famous (from the standpoint of traditional philosophy) of Aristotle's works, the *Metaphysics*, may be said to be devoted primarily to the problem of man's knowing the Universe, or Cosmos, approached from the direction of the Whole-and-its-parts.

But it is obvious that "our usual method

of investigation" could not be followed here without far-reaching modification. For the "compound whole" to be analyzed into its "uncompounded elements" (Weldon, 1912, p. 2) was certainly not accessible by the principles of knowledge-getting he himself had so largely developed and utilized. The method could be applied with considerable success in getting knowledge of a State or a work of art, as a poem (this article, part I, QUART. REV. BOL., Vol. 7, p. 381), or a bedstead (p. 387), or a block of ice (p. 383), or a bit of air (p. 384). But when it comes to the universe—what is it compounded of?

Yet, there is the sun, the moon, the planets, the starry hosts and the arching sky, no less truly things of sense experience than men and fishes, the blue sea, and the solid earth. Surely the heavenly bodies are parts—of something—no doubt about that. But of what? What is the whole now? Can there be a whole so big and inclusive that there is nothing beyond it, nothing left out of it?

No one who has faced seriously the problem of the One and the Many, as even we moderns are perplexed by it, can be decently indifferent to the magnificent onslaught upon it made by the Greeks nor unsympathetically critical of their meager success.

The study of what Aristotle did on the problem may well begin with a reference to the view, now apparently accepted by nearly all students of the Aristotelian works, that the *Metaphysics*, the work in which the deepest meaning of existence is treated, was not called *Metaphysics* by its author. *The First Philosophy* was his name for it. The main significance of this is that really *Theology* would probably indicate more truly what Aristotle was here aiming at than does *metaphysics* as commonly understood. For he was obviously quite

as interested in the problem of God as in that of Nature.

The moment we touch the question of what the ancients (any of them) did on the problem of Everything, we are confronted with the pitiful meagerness (as compared with ours) of their factual knowledge. And much of this meagerness stands in relation to every division of nature, it stands with special importance in relation to the heavens. Undoubtedly facts in this subdivision are among the most striking and appealing of those in any subdivision whatever. But from their very nature they are specially beguiling to common experience. Wonderful, indeed, is the rising and setting of the sun, the effects of its radiations upon the earth, and the responses to these radiations by living bodies. Nevertheless so far as concerns all land-and-air inhabiting animals, man with the rest, problems of finding, securing and utilizing food and water are manifestly much more compelling of attention and goading to action. The growing light and warmth of each new day just comes, as free grace, to the mother bird and to the mother human. Nothing is exacted of the recipients—unless indeed the stimulus to song by the bird and prayer of thanksgiving by the woman be counted as exactions. How different the advent of the day for both creatures relative to food and drink! Be up and doing is the exaction now. For the final issue is Life-or-Death. And this must be met quite otherwise than by benisons of song or prayer, however desirable and good these may be.

So while perhaps knowledge of the heavenly bodies is the oldest branch of natural science, it certainly is not the oldest branch of practical experience. And who has a scintilla of real evidence of theoretic or speculative knowledge in any realm whatever that does not rest finally on practical

experience, individual and racial? Herein matters of the most human concern are the issue.

History reveals that men in all ages have applied their imaginations and speculations to their free-grace experience of the heavenly bodies with the hope of gaining help therefrom in their active, often hard, experiences of such earthly bodies and situations as are Life-or-Death to them.

To this Aristotle was not apart from his predecessors and contemporaries. Indeed he seems to have been behind some of them in some respects. But we cannot in decency be unsympathetic with our forebears in this if due regard is had to the study of astrology among peoples and cultures down to our very selves with our daily newspapers as media for disseminating astrological beneficence and malevolence.

With reference to Aristotle's position in this, our concern is, as in other matters, quite as much with his *thinking* on the basis of the factual knowledge he possessed, as with his *knowledge itself*. And our main interest is, of course, the question of how his conception of *entelecheia* stood in relation to his conception of Everything, especially as to the heavens as a part of Everything.

It is significant that in the discussion which embodies his conclusions about the nature of the heavens and of God, Aristotle begins not with the heavenly bodies but with substances, matter and movements; and with actuality, potentiality, and cause. In other words he begins where common experiences begin, namely, with earthly things.

As an illustration of how objectively real he was, take this: "For how will there be movement, if there is no actual cause? Wood will surely not move itself—the carpenter's art must act on it." (*Metaphys.* 1071^b 28, Ross trans.). Then, true to his custom as a student of genesis, there immediately follows: "nor will the *menses* nor the earth set themselves in motion,

but the seeds must act on the earth and the *semen* on the *menses*." Philosophically sound but scientifically very unsound, you see—as in many other instances.

How then is man—individual man—whose existence is dependent on the act of procreation by a man and a woman, and on innumerable acts of his own in securing and utilizing nutritial substances, going to fully comprehend *Everything*? Sharply and certainly limited as a man is both in coming to be and in continuing to be, how can he encompass in any sense, by his own acts, even by his most powerful and comprehending acts, that which is entirely unlimited, so far as his experiences testify?

The evidence is conclusive, I believe, that on the whole Aristotle approached the great problem in this humanly animalistic fashion.

But what could he really do toward solving it? Almost absolutely uninformed as he was of the facts and interpretations on which the idea of organic evolution rests; pathetically meager as was his technical information about reproduction and development, about nutrition, respiration and metabolism, about neuromuscular action, and about the physics and chemistry of the external environments of living things, there was no course open to him by which he could advance beyond what others had done than to put enormous dependence, just as they had done, on thinking and reasoning about such observational data as they possessed. Now this sort of thing implied (as it always does) discussion, argument, speculation, disputation. It meant *dialectics*. And dialectics is a method of striving after truth that has had tremendous vogue in the history of human culture. And there is much uncertainty as to whether the balance sheet of such striving shows truth in the black or in the red.

A great part of Aristotle's effort to solve the problem of All Existence was made

by applying this very method. There is no doubt about it. Accordingly his results have to be tested by this criterion as well as by that of observational procedure and inevitable logic.

Against the theory that number is in essence such as to be the sole explanation of Everything; also the theory that Platonic Ideas hold this exalted place Aristotle levels his great dialectic powers. How successful he was in this, I do not undertake to judge. Nor does it seem to me of much importance, its significance being historical and logical rather than factual. Of far greater importance is the circumstance that at a deeper, more vital level of his information and his thought, he recognized that a *sine qua non* to any body's having information or thoughts about the nature of numbers or of Ideas or anything else is the fact of being alive with all this implies as to begetting, birth, growth and differentiation; also as to many vastly complex organic functions especially of digestion and metabolism, and of sensitivity.

ARISTOTLE'S THEOLOGY AND ENTELECHEIA

That he tripped a few times when he tackled the problem of Everything, is not surprising. Indeed, all things considered, it is wonderful that he did as well as he did. And I venture to contend that his faithfulness, on the whole, to his conception of *entelecheia* was a major factor in his accomplishing whatever of value he did accomplish here.

Let us examine then the question of what exactly he did toward squaring this conception with his dialectical efforts. We can use Ross's *Selections*, (Ross, 1927) to good advantage. The group of selections combined by Ross under the title "Aristotle's Theology and Astronomy," begins (in keeping with what we pointed out

above about Aristotle's starting his discussion of the Heavens with his earthly experiences) as follows:

Since there were three kinds of substance, two of them physical and one unmovable, regarding the latter we must assert that it is necessary that there should be an eternal unmovable substance. For substances are the first of existing things, and if they are all destructible, all things are destructible. But it is impossible that movement should either come into being or cease to be; for it must always have existed." (*Metaph.* 1071^b 1-7.)

This problem of substance is upon us here in its full terribleness. As for the two physical kinds, the material, or substratum of bodies, and the bodies themselves as forms, Aristotle was no more dubious about them than is any consistent modern naturalist (a naturalist, that is, who has not become sophisticated by atomistic physics). It was the third kind, the unmovable kind, that troubled him most. For even though he found great difficulty in making it fit with the other kinds, he still thought he could not get along without it. And one of the particularly hard questions in connection with it was that seemingly it must be non-sensible.

"For (1) it [*Physics*] does not deal with the final cause (for this is the good, and this is found in the field of action and movement; and it is the first mover—for that is the nature of the end—but in the case of things unmovable there is no first mover), and (2) in general, it is hard to say whether the science we are looking for [i.e., "Wisdom as a science of first principles"] deals with perceptible substances or not with them, but with certain others." (*Metaph.* 1059^a 35.)

"Hard to say" indeed! For even today where are we with reference to it? Modern physics seems actually to have fallen behind Aristotle to the extent that it is now staking everything on atoms as experimental analysis knows them and as they can be treated quantitatively. Nor have the prevalent schools of philosophy, ethics and religion, made clear and solid advance beyond him. For in none of these has sub-

stance as form in the sense of Aristotelian morphology received any approach to adequate recognition. So the question we are asking boils down to this: What did Aristotle do toward reconciling his "usual method of investigation," i.e. of "analysing a compound whole into its least parts," with his supposed necessity in a particular case, that of the problem of Everything, of proceeding by the reverse method? For as we see, he really began with the parts (least parts?) in this case and tried by the dialectic method to conceive the whole. Here is a passage that seems to me to go far by implication toward answering the question.

Arguing for his theory of a "first" agent as the cause of all objectively known things he says:

Since (1) this is a possible account of the matter, and (2) if it were not true, the world would have proceeded out of night and "all things together" and out of non-being, these difficulties may be taken as solved. There is, then, something which is always moved with an unceasing motion, which is motion in a circle; and this is plain not in theory only but in fact. Therefore the first heavens must be eternal. There is therefore also something which moves them. And since that which is moved and moves is intermediate, there is a mover which moves without being moved, being eternal, substance, and actuality. (*Metaph.* 1072^a 18-25 Ross trans.).

The crucial point here is that the last word of the passage is actuality (*energeia*) and not complete reality (*entelecheia*). May we not properly ask why this eternal substance that is insensible and is a mover of the heavens and all things without itself being moved, should not be characterized as complete reality and not merely as actuality? Is it not justifiable to conjecture that the remarkable something that Aristotle here assumed he at the same time felt to be lacking the sort of reality that led him to conceive *entelecheia*? Reflect on the incongruity of applying the same term to such a phenomenon as he supposed the

heavens to be, that he applied to the phenomenon of the transformation of ice into water (this article, part I, QUART. REV. BIOL., Vol. 7, p. 383) or of the change of a warm body to a cold one (p. 384).

The difficulty of observing all that is observable of any whole-and-its-parts, regardless of size and complexity, and of thinking about it, and being entirely consistent throughout, is undoubtedly very great. Yet that such consistency was what Aristotle really felt the need of when he conceived *entelechia*, appears to me certain. How difficult it is to measure up to the aim is illustrated by the fact that Aristotle himself almost certainly fell short now and then. An important instance is furnished by his efforts in connection with this very problem of Everything. He, like innumerable other persons in many ages and cultures down to some of the distinguished astronomers and all of the astrologers of our own day, conceived the heavens to be the region which is the favorite, if not the exclusive abode, of the eternal and divine. With Aristotle movement was, as we have noticed, what he regarded as particularly convincing objective evidence of the eternal. For the dialectical proof of the endlessness of movement in a circle seemed to him conclusive. And since this was supposed to be the course traveled by the heavenly bodies, they furnished proof of eternity and divinity. His discussions of the heavens, especially in the *De Caelo* and the *Metaphysics*, make it clear that his interest here was at least as much theological as scientific. In these discussions he seems to flatly contradict his conception of *entelechia* in one instance. And it is fair to guess, I think, that his contradiction is due to the dual interest indicated. The contradiction occurs in the following passage.

"Evidently there is but one heaven. For if there are many heavens as there are many men, the moving principles, of which each heaven will be one, will be

one in form but in number many. But all things that are many in number have matter. (For one and the same formula applies to many things, e.g., the formula of man; but Socrates is *one*.) But the primary essence has not matter; for it is complete reality (*entelechia*)." (*Metaph.* 1074^a 36, Ross trans.).

It is in connection with this passage that Ross writes me (without knowing of my reference to it here): "Yet for the most part Aristotle uses the words (*entelechia* and *energeia*) interchangeably. Ross also writes "*Energeia* was not a well-established Greek work. It, no less than *entelechia* seems to be a coinage of Aristotle. At least the new Liddell and Scott has found no earlier use of it." Such being the case, is not the question a fair one: Why should Aristotle have coined two such important words if they were quite interchangeable in his thought?

The statement that complete reality has not matter is unreconcilable, so far as I can see, with the many assertions, direct or by clear inference, that complete reality does include matter. The instance of ice and water, and of warm and cold referred to above may serve as examples in the purely physical (modern sense) realm. A footnote to this passage by Ross seems to furnish similar evidence for the biological realm. "The Logos," says the note, "is common to all men, so that it must be matter which gives Socrates his uniqueness."

It may be contended, and it is probably true, that the matter assumed to be responsible for Socrates' uniqueness is wholly different from the "primary essence," of the passage, and which is the "complete reality" of it. But this really helps to focalize my criticism. For evidence is unescapable that Aristotle was fully committed, as a biologist, to the idea that the germ of man as of organisms generally was potentially the organism in its actualized form so far. In other words, he was committed to the modern idea of heredity as to propagation, and to epigenesis as to ontogeny. More of the passage in *De Partibus* quoted (this article, part I, QUART. REV. BIOL., Vol. 7, p. 386) is especially clear on

the point: "Every germ implies two organisms, the parent and the progeny. For the germ or seed is both the seed of the organism from which it came, of the horse, for instance, from which it was derived, and the seed of the organism that will eventually arise from it." (*De part.* 641^b 33-37). This is, so far as matter is concerned, in accord with the fully established facts of genesis and is opposed to the theory of something, a primary essence, for example, in addition to the matter. For even the germplasm theory, though holding that the germinal substance does not really come from the parent, does not invoke an essence or first agent, or cause in the meaning of Aristotle when he departs from his usual course as a student of living nature and becomes genuinely metaphysical as a speculator about the heavens.

Attention may be incidentally called to the fact that the theory of germinal mutation of the ultra-orthodox school of genetics is perilously near, in logic, to the Aristotelian theory of a non-material first agent, or essence as the cause of the mutations, that is, of the source of new species.

Fortunately, as it seems to me, Aristotle connects his theories of thought and of motion in such a way as to give added justification to the view that he contradicts himself when he uses *entelecheia* in the instance cited. The passages I am about to quote will be more easily seen to bear on the point if read in connection with our examination of Aristotle's views about pleasure in relation to thought. Directly continuous with the passage quoted above and ending with "there is a mover which moves without being moved," etc., we have: "And the object of desire and the object of thought move in this way; they move without being moved. The primary objects of desire and of thought are the same. For the apparent good is the object of appetite, and the real good is the primary object of rational desire"

(*Metaph.* 1072^a 26-28 Ross trans.). Then comes a long discussion of the intermingling of things distinctly earthy with things heavenly. In this discussion the concept of actuality (*energeia*) plays a large part while that of complete reality (*entelecheia*) plays no part at all. Some of the instances follow:

"Since there is something which moves while itself unmoved, existing actually, this can in no way be otherwise than it is. (1072^b 7) . . . On such a principle, then, depend the heavens and the world of nature. And its life is such as the best which we enjoy, and enjoy but for a short time. For it is ever in this state (which we cannot be), since its actuality is also pleasure (1072^b 15) . . . If, then, God is always in that good state in which we sometimes are, this compels our wonder . . . And life also belongs to God; for the actuality of thought is life, and God is that actuality; and God's essential actuality is life most good and eternal. We say therefore that God is a living being, eternal, most good, so that life and duration continuous and eternal belong to God; for this is God." (1072^b 25).

Another, more literal at least in part, translation of the last sentence is: "Now, our statement is, this,—that the Deity is an animal that is everlasting and most excellent in nature; so that with the Deity life and duration are uninterrupted and eternal: for this constitutes the very essence of God." (M'Mahon, 1910, p. 332). The passage in which this occurs is regarded by M'Mahon as probably "the most lucid statement of Aristotle's notions of the Divine Nature of the Being and Attributes of God."

That God is a *Zoon*, everlasting and very good; and that *Zoe* is life co-enduring with God is surely deserving of special attention as indicating the remarkable contrast between the Greek conception of animal and the well-nigh universal modern conception of it.

In the light of what has been already presented in this essay, is it any wonder that Aristotle should find no place for his conception of *entelecheia* in the reasoning these statements present? Surely, the conception of God as an animal in the sense that fish, bird, mammal, and man are species of the genus animal would be as con-

trary, even as repugnant, to the general spirit of the Aristotelian science and philosophy as to that of any system whatever of science, or philosophy, or ethics, or religion. Yet rigid adherence to the cardinal principles of biology and logic, of both of which Aristotle is the acknowledged founder, would seem to commit him to just that conception.

Such a passage makes one wonder whether it may have been written (or spoken?) long before its author had immersed himself in the study of living nature and of the psychical processes involved in the study, and that he never took it up again in earnest. The problem of the chronological order in which the Aristotelian works were produced, to which experts are now giving serious attention, shows its great importance in such passages.

If, then, my interpretation of Aristotle's system of knowledge and thought, and especially of his conception of *entelecheia*, is on the whole sound, the mental picture of the man and his system must be very different from that which seems to hang in the mental galleries of most of those in which there is any picture of him at all. For see what in barest outline such a picture portrays:

A man insatiably curious about, and determined to know and understand as far as possible, everything whether of earth or heaven.

Committed to the gigantic task thus implied and attending greatly to the psychical activities involved in the task, the man pictured blocks out for the earth as a compound whole the domain of natural science with a comprehensiveness and, for living things, a detailed truthfulness that no one before him had remotely approached.

For all the earthy portion of the task, the pictured man recognizes with remarkable insight that interpretation of a whole-and-its-parts requires a conception for which he coins the term *entelecheia*.

As to every aspect except one of the terrestrial portion of the task, he is presented as satisfied that his new term is applicable. The exception he seems to feel concerns the power of reason as possessed by a single animal species, man. Here, seemingly after considerable perplexity, he decides that his new term does not apply. This power is too great, too precious, too divine, to be included even in man's completeness as an earthly being.

Finally when he who is pictured comes to the problem of the heavens, the celestial position of his task, he appears still more perplexed as to the status of his new conception. Now we seem to see him falter between two stupendous alternatives: (1) Must he conceive the heavens as the abode of Deity—yes, in ultimate essence very Deity itself—to be entirely unknowable, inaccessible, to earthborn man? Or, (2) May he conceive the heavens and God not thus beyond the reach of man if man be conceived in one of his parts, his reason, to differ from himself as earthborn, in just the way requisite to give him the power of knowing God?

In neither alternative, notice, could *entelecheia*, earth-engendered as we have seemed to find it, be strictly and fully applicable.

MODERNIZED ARISTOTELIANISM

What, we may now properly ask, would be necessary to transform this mental picture of the relatively little informed ancient Aristotle into the picture of a modern man, enormously informed as he may be?

Can there be serious doubt as to what the revised picture would show? Recur to the problem of the soul as Aristotle struggled with it—the problem of whether there are three souls, or one soul with three parts, nutritive, sensitive, and rational. Examine this in the light of the principle of the whole-and-its-parts which Aristotle

himself clearly saw in many of its aspects. Examine it also in the enormous addition of light from present-day anatomy, physiology and chemistry of nutrition and of stimulus-response and the higher and highest mental activities.

From such an examination conjoined with a firm grip on what Aristotle aimed at by his term *entelecheia*, the conclusion seems to me unescapable that no such giant intellect as his is essential to see that the complete reality of a man *does* include his attribute of reason regardless of how varied, or subtle, or mighty it may be.

Now this is a way of saying that in inventing the word *entelecheia* Aristotle saw conceptually farther into the nature of man than the meager factual knowledge he possessed seemed to warrant.

Further, it is a way of saying that the dualism of Soul and Body, of Mind and Matter, as this has plagued much of human culture disappears when subjected to the joint light of the best Aristotelian thought and the best analytical results of modern research.

But if the revised picture would portray one eagerly willing to include his own highest, most cherished powers among his earthborn possessions, even more would it portray one willing to include the heavens regardless of how divinely conceived, as inseparably linked with the earth to constitute the Grand Whole of Things. For reflect on what the astronomy, the physics, and the chemistry of our era have done to confirm objectively not only Aristotle's reasoned conclusion that "there is but one heaven," but that this one is by no means utterly cut away and different from mother earth. Had Aristotle possessed as much observationally verified information about the movements of the earth, the other planets, and the stars; about gravitation; about the chemical composition of the sun and other heavenly bodies; about

the nature of light and heat; about the electro-magnetic conditions of the earth and the sun; and about radiation, as enters into the common knowledge of our day, it does not seem to me at all probable that he would have staked as much as he did on the nature of the heavens in contrast with the nature of the earth, in constructing his theory of the eternal and divine—in a word, his Theology. And this is equivalent to saying, according to the viewpoint of this essay, that under such conditions he would not have hesitated to conceive *entelecheia* (Complete Reality) in such a way that it would extend to both Earth and Heaven and all that in them is, man and all his powers by no means excepted.

LIMITATION OF ENTELECHEIA

But even though *entelecheia* would extend thus far it would not imply coexistence with, for instance, the Hebrew Yahveh or the Mohammedan Allah. For these names seem to have been designed to be all other Names above; Names, that is, that should designate Being and Power adequate for all needs, desires, and hopes of human hearts and heads.

An extended discussion of the portion of Everything that extends beyond the meaning of *entelecheia* is for that very reason beyond the scope of this essay. One aspect of the problem may, however, be appropriately noticed to the extent of a few sentences.

It would seem that Everything Whatever would have to include all that now is, all that previously has been, and all that thereafter will or may be. In other words, All Existence thus conceived must be coextensive with Space and Time (as generally understood). Now due consideration for the principles of potentiality and actuality (and great consideration we have seen Aristotle giving them) seems to require the recognition that All Existence

Whatever would have to include not only all that has been or now is actualized of all potentiality, but all that might possibly be actualized. But the concept of *entelecheia* really includes, according to our interpretation, only so much of potentiality as has been and is now being actualized. That is to say any potentialities that a body or situation may have that never become actualities would not be included in the concept. To illustrate, any potentialities a human infant may possess which never come to actuality even though a well-rounded three score years and ten or more may be lived, would not be included in the *entelecheia* of that individual. By this view the "complete reality" of a human life, no matter how full of years and good deeds it may be, would not include those possibilities it had at the beginning that were never realized. Immeasurable (infinite?) potentialities or possibilities would therefore exist that would not come within the meaning of *entelecheia*, but would come within the seemingly intended meaning of the Divine.

So it results that enormously meaningful and useful as *entelecheia* is for natural science and natural philosophy, it falls short of adequacy in its application to All Existence Whatever. The "complete reality" of the concept is not complete enough, as one may say, to include fully that aspect of man's response to nature for which in all his ages and cultural stages he has sought satisfaction, and to the summed-up, abstracted object of which he has given the name God in one or more of its numberless synonyms and variants. The flood of stimuli from the external world that pour constantly upon us as raw material of emotional experience—how vastly this exceeds, we now realize, our ability to give rational, analytic attention to it in all its details!

Accordingly for an adequate under-

standing of man's response to Nature, especially in the emotional moiety of that response, we must go elsewhere than to the teachings of Aristotle. Or, perhaps more exactly, for such understanding the Aristotelian teachings must be amended and extended to make them conform with the information and ideas concerning Nature embodied in the world-culture of our era.

The presentation of what, so far as I have grasped it, the suggested amendment and extension would consist in, belongs to quite a different essay from this. Here a mere hint in that direction must suffice:

In accordance with the psychologically well-recognized importance of distinguishing between any emotion as such, and the reasoned interpretation of that emotion, it turns out that the sharpest kind of distinction needs to be made between the mystic experience just as an emotion and the rational explanation of that experience. For such an explanation constitutes a theory, or doctrine commonly called mysticism. So mysticism has no necessary connection with religious experience.

That emotional state, which is basic to the so-named mystic experience, can be entirely identified with our sensory responses to Nature and our absolute dependence on Nature. It can be shown that almost certainly the "sense of oneness with God," of the devoutly orthodox Christian; the "Substance," one and eternal, of Spinozian philosophy; the "immediate experience of the whole occurrence of Nature" of a professedly atheistic naturalist like John Burroughs; and "my mystic world lovely with trees and clouds and eddying streams I have never 'seen'" of sightless persons like Helen Keller, are responses to nature not so much in its infinity of space and time as in its organized completeness. By this interpretation Omnipotence is an attribute of Nature: Omniscience does not exist, because nescience is an attribute of a part only of nature, that is to say, of man. (Ritter, 1933 pp. 18, 19.)

Such an emotional-intellectual attitude toward Nature as that here sketched is one concomitant of the acceptance of the Universe, the phrase being understood as in this second Foreword.

Apparently this is the aspect of man's

response to nature that makes him "incurably," as the expression has it, religious just as, from another aspect of his response, he is "incurably" curious and intelligent; also scientific and philosophic.

That the world is vastly more indebted

to Aristotle (and other Greeks) for logic, science, and philosophy, than it is for religion, should no longer stand in the way (as for centuries it has stood) of the world's entering into the enormous benefits of that indebtedness.

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OBSERVATIONS ON THE GENERAL BIOLOGY OF THE FLOUR BEETLE, *TRIBOLIUM CONFUSUM*

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INTRODUCTORY REMARKS

T*TRIBOLIUM CONFUSUM*, the flour beetle, possesses characteristics which commend it to the attention of experimentalists. It is cosmopolitan and easily obtainable; it has a moderately short life-cycle; it is hardy and requires no elaborate equipment for its maintenance; both adults and immature forms are readily recoverable from the medium for study by a simple technique, and it spends its entire life-history in various pulverized grains such as flour. As has been pointed out before, this latter feature is particularly advantageous in many kinds of experimentation since, with a total environment such as flour, considerable stability of both intra- and extramedium relationships can be obtained. By using similar flour in all experiments and by expressing this flour quantitatively in terms of weight and surface exposure, as well as surrounding the flour by as constant external conditions as obtainable, a total environment can be established which is relatively quite constant and reproducible. Despite these attractive requisites it is only recently that *Tribolium* has come to the attention of biologists interested in theoretical problems. The economic zoölogists have been vigorously aware of the existence of this form for many years and have done much in providing data on the general ecology of the species. However, past this point, these workers, possibly unfortunately, have

seemed more interested in devising methods of exterminating the form than recommending it to the attention of experimentalists. Babcock (1912), an early worker with *Tribolium*, used this beetle in studying the problem of metabolic water, finding the insect maintained a tissue water level about 40 per cent greater than the moisture content of an environment containing 10 per cent water. Davey (1917, '19), another early investigator, reported results showing that the length of life of these beetles could be prolonged if mass cultures received a small daily dosage of X-rays. Probably the principal credit in introducing *Tribolium* as an experimental organism, however, belongs to R. N. Chapman who in 1918 reported on its life-history, in 1924 on its nutritional requirements, and in 1928 on its suitability for population study. These papers will be discussed at length later: it is only important at this point to remember that they emphasized the practicability of *Tribolium* for experimental purposes by presenting a technique of handling the beetles as well as actual data. Since *Tribolium* does seem destined to merit more experimental attention, and since experimentalists need a factual background about the animal of their endeavors, it seems permissible at this stage to review fairly completely certain details about the flour beetle in the hope that such a review will be helpful and possibly stimulating to future investigators in the field. With this in mind the following general topics

about *Tribolium confusum* will be dealt with: first, taxonomic and historical considerations including a brief discussion of closely related species; second, a review of the food relationships of the flour beetle along with discussions of certain nutritional problems; third, a detailed discussion of the life-cycle and its relation to environmental factors; fourth, a discussion of productivity (fecundity and fertility); fifth, a treatment of some of the obvious behavior reactions of the beetle from both a statistical and an observational viewpoint, including some original observations upon cannibalism, copulation, and defecation; sixth, notes on the parasites of *Tribolium confusum*; seventh, a discussion of the technique of culturing and studying populations of the flour beetle, and last, a summary. It should be pointed out that no attempt will be made to cite or deal with every paper which has been written on *Tribolium*. This would be futile and not pertinent to the problem at hand due, in part, to the economic nature of many of the reports. The emphasis will be placed on a discussion of those investigations yielding information most likely to be required by future workers confined primarily to experimental research.

TAXONOMIC AND HISTORICAL

The genus *Tribolium* is a member of the Order Coleoptera, Family Tenebrionidae and sub-family Ulominae. The Tenebrionids are commonly referred to as the 'Darkling beetles' and include such forms as certain fungus-beetles, the pinacate-bugs, and the common meal worm *Tenebrio molitor* which has certain points of resemblance to *Tribolium*. There are several other species of *Tribolium* besides *confusum*. The other common American form is *Tribolium ferrugineum* Fab. Doctor Good, of the Department of Agriculture, informs me that the latter species is probably more properly

referred to as *Tribolium castaneum* Hbst. These two American flour beetles seem to be remarkably similar in general structure and function. There are several criteria used by taxonomists in distinguishing the two from each other. *T. ferrugineum* = *castaneum* possesses a distinct three-jointed antennal club while *T. confusum* has a gradually enlarging club. Good (1933) points out the fact that the eyes of *T. confusum*, when viewed from the ventral surface, are smaller than those of the other species. The evidence at hand indicates that *T. confusum* has, in general, a more northern range of distribution than *T. ferrugineum* = *castaneum*. This paper will deal entirely with *T. confusum* largely because more is known of its general ecology. It should be emphasized, however, that the other species would probably lend itself as well to experimentation.

At the present time the genus *Tribolium* is very widely distributed over the world. It is largely disseminated in grains transported by commerce. The exact origin of the grain dwelling habit is not known but a probable interpretation is advanced by Good (1933: p. 328) who says,

Almost without exception, the beetles of the subfamily Ulominae, of which *Tribolium* is a member, occur either as pests of stored products or else under the bark of trees and in rotting logs. It seems evident that all members of this group originally lived in the latter habitat and have recently adopted the flour-feeding habit. Two species of *Tribolium*, *T. madens* Charp. and *T. indicum* Blair, are found almost exclusively in such situations, and the two flour pests *T. confusum* and *T. ferrugineum* are themselves occasionally found there.

Tribolium confusum was really first described unknowingly by Etienne Mulsant who, in attempting to improve upon the account of the already known *Tribolium ferrugineum*, published a description of *confusum*. However, since Mulsant thought he was simply redescribing *T. ferrugineum* his reference to *confusum* has been ne-

glected. The credit of the description has been ascribed to P. N. Camille Jacquelin du Val who in 1868 recognized *Tribolium confusum* as a distinct species and published his account. Due to the fact that du Val's (now commonly written Duval) description typifies much of the taxonomic work of his era it is considered permissible to append it below as it existed originally.

(1) *Tribolium confusum*, Jacq. du V.

T. ferrugineo simillimum, et descriptio ulterior supervacua. Ab illo differt capite latiusculo, genis ad oculos distinctius angulatis, pronoto postice leviter sed distincte sensim angustato, cum angulis posticis acutiusculis, interstitiis elytrorum paulo magis elevatis et praesertim antennis sensim elevatis. —Long. 0,0034-42.—

Je dois ajouter pour compléter la distinction des deux espèces en question que, chez le *T. ferrugineum* la tête n'est pas plus large que longue et offre des joues très obtusement angulées auprès des yeux, le pronotum est légèrement et régulièrement arqué suré les côtés, n'est pas plus large ou même est un peu plus étroit en avant qu'en arrière et offre des angles postérieurs droits, mais sans former de pointe saillante, enfin les antennes sont terminées par une massue très distincte et assez brusque de trois articles, tandis que chez le *T. confusum* la massue est insensiblement formée par les 4 ou 5 derniers articles. L'espèce que je viens de signaler se trouve confondue dans diverses collections françaises avec le *T. ferrugineum*, et a été décrite pour cette dernière par M. M. Kuster et Mulsant. La phrase suivante, "*Antennae articulis tribus perfoliatis*," insérée par Fabricius dans son *Supplementum Entomol. Syst.* p. 179, nous fixe sur l'espèce de cet auteur. Le *Colydium castaneum* de Herbst appartient aussi à n'en pas douter à cette dernière. Quant à l'*Ips cinnamomea* de Herbst, la figure qu'en donne cet auteur démontre que ce ne peut être un *Tribolium* ni même à mon avis un Ténébrionide." (p. 181)

FOOD AND NUTRITION

Tribolium confusum lives in almost any kind of flour, cracked grain, breakfast food or meal. A list of specific foods in which these beetles are found has been compiled by Chittenden (1896, 1897) and includes whole-wheat flour, bleached and unbleached white flour, bran, rice flour, rye flour, corn meal, barley flour and oat meal. Good

(1933) also reports the beetles living in chocolate, spices (red pepper), various kinds of nuts, and sometimes feeding on specimens in insect collections. Chittenden has found *Tribolium* in snuff, orris root, baking powder, ginger, slippery elm, peas and beans. The beetles are unable to feed on whole grains, as pointed out by Chapman (1931), because their mouthparts are not adapted for attacking large, hard pieces of food. Typically, the entire life-history of a *Tribolium* is passed within its original environment.

Chapman (1918) has studied the relative susceptibility of wheat flour to the invasion of *Tribolium* in order to determine, as he states it, if there is any 'preference' exhibited by adult beetles for specific flours. This investigator divided an experimental jar into five equal portions each containing a different kind of wheat flour which varied from finely ground flour (first middlings) to bran. These flours were in continuity with each other so that a beetle could pass from one type to another. Then adult *Tribolium* were introduced into the center of the jar, and, being surrounded by equal parts of the five types of cereals, were allowed to migrate. After a varying length of time the flours were examined and a census made of their beetle population. Chapman found that the bran contained essentially twice as many beetles as did the other media and concluded that these data indicated a preference selection on the part of *Tribolium*. In repeating the experiment with larvae no evidence of such a 'preference' was found. Observations were also made with rice flour, rye flour, barley flour and corn flour and the results of these experiments, in harmony with the first ones, indicated that the beetles were reacting, not necessarily to the richest food, but to the most coarsely ground medium. Chapman ingeniously tested this further by running a varying series of sawdusts

differentially ground and again corroborated the fact that the beetles react positively to the coarse material which they can enter readily and move through with facility. However, after the experiments had run a longer time it was observed that all of the flours, whether coarse or fine, were equally populated. This was due to the fact that the beetles eventually honeycombed the finely ground flour with tunnels and were then able to move freely through it.

Chapman (1924) reared *Tribolium* on various media and concluded, first, that microorganisms did not play an important part in their nutrition; second, that the nutritional requirements for growth, or increase in size, were less exacting than those for maturity or metamorphosis, and third, that wheat germ most closely satisfied these physiological requirements. Sweetman and Palmer (1928) investigated the vitamin requirements of *Tribolium*, and found that Vitamin B was necessary for their development. Their investigations showed that the wheat embryo was a rich source of Vitamin B. The conclusion to be drawn on the basis of these experiments seems to be that flours represent a well balanced diet and that *Tribolium* is typically able to live in them with its complete nutritional requirements well satisfied.

Under the caption of nutritional effects it might be interesting to mention briefly certain experiments of Holdaway (1933) dealing with the effect of starvation on sex ratio. This investigator subjected first instar larvae to different degrees of starvation as follows: the first group served as controls and were not starved; the second group received one day of starvation; the third group two days starvation, and the fourth group three days starvation. These experimental groups were incubated until the pupal stage was reached at which time

sex was determined. The larvae starved one day exhibited a higher proportion of males than did the controls. This proportion did not exceed the limits of random sampling and can not be taken too seriously. However, the groups starved two and three days showed a statistically greater number of females than the controls. This was a significant difference. Holdaway shows that this alteration of sex ratio can not be explained on the basis of a differential mortality existing between the sexes and concludes that the starvation is the critical factor.

Certain other observations have been made on the physiological effects of various kinds of foods upon *Tribolium* and these will be discussed in later sections of this paper.

METAMORPHOSIS AND LIFE-CYCLE

Many references to the life-cycle of *Tribolium confusum* may be found in the literature. Most of these reports are incomplete, abbreviated, and frequently incorrect. In most ways, the best statements on the subject are those of Chapman (1918), Brindley (1930), Holdaway (1932), and Good (1933). These papers all present the results of original observation and do not resort to the recopying of often erroneous textbook statements. In the present discussion on *Tribolium* metamorphosis and life-history the information will be drawn largely from these four papers. For a succinct account in German the papers of Zacher (1927, '33) and Künike (1931) can be recommended. Other pertinent references are those of Chittenden (1896) and Dean (1913).

As is typical with holometabolous insects, *i.e.*, forms displaying complete metamorphosis, *Tribolium confusum* possesses in its life-cycle, egg, larval, pupal, and adult stages. In order to clarify this discussion it is deemed wise to describe briefly these various types.

The eggs are ovoidal in shape when naked but usually appear somewhat irregular due to the fact that they are surfaced with flour particles which adhere to the sticky egg membrane. Brindley (1930) reports the following egg measurements: mean width, .40 mm., mean length, .64 mm., with a standard deviation of .02 and .04 mm., respectively. Chapman (1918) draws attention to the fact that the contour and general appearance of the eggs varies somewhat according to the type of medium in which they are found. Thus eggs in finely milled wheat flour would appear smaller than those from coarser cereals. Stanley (1932) determined the mean moisture content of 30,000 eggs and found it to be 44.9 per cent.

The eggs hatch into small, white larvae which measure, according to Brindley, on the mean 1.18 mm. in length, and 0.18 mm. across the head capsule. The first instar larvae weigh 0.028 mg. The moulting behavior of the larvae may be described in the words of Chapman (1918, p. 75) who says,

• For a short time before each moulting, the larva is inactive and the body is large in proportion to the head. The skin splits dorsally over the head and thorax, and the larva emerges. It is at first white, like the larva of the first instar, but after twenty-four hours it takes on a yellowish color. Immediately after moulting, when the larva has expanded as a result of being freed from the old skin, it has often been observed to remain quiet for a time.

An interesting question with regard to *Tribolium* metamorphosis is that dealing with the number of larval instars. Chapman and Brindley, both reporting original observations, have noted that there are six larval instars in the development. These writers measured the larval head width during the different instars and used this as a criterion of development: i.e., a certain head width indicated a specific larval stage. Good (1933) studied the

number of instars by counting the number of exuviae (larval skins) deposited in the flour after each larval moult. This author concludes (p. 331): "... the writer has determined that there is no fixed number of larval moults, but that the number ranges from 6 to 11 or more and is normally 7 or 8 instead of 6. This variation is due both to external conditions, such as food, temperature, and humidity, and to individual characteristics entirely apart from external influences."

The larvae gradually increase in size with every moult: Brindley shows the fourth instar larvae, for example, to have

TABLE 1

Larval measurements of Tribolium confusum. (Taken from Brindley by permission of the Ann. Ent. Soc. Am.)

INSTAR	AGE IN DAYS	LENGTH		HEAD CAPSULE WIDTH		WEIGHT
		Average	Standard deviation	Average	Standard deviation	
		mm.	mm.	mm.	mm.	mg.
1	0	1.18	0.05	0.18	0.01	0.028
2	3	1.64	0.11	0.22	0.03	0.035
3	6	2.38	0.08	0.29	0.01	0.119
4	9	3.23	0.20	0.40	0.01	0.332
5	12	4.00	0.44	0.53	0.04	1.09
6	15	6.00	0.70	0.69	0.03	2.40

a mean length of 3.23 mm., a head breadth of .40 mm., and a weight of .332 mg. The last instar larvae are 6.0 mm. long, .69 mm. broad across the head, and weigh 2.4 mg. As the time for pupation advances these last instar larvae become more and more quiescent and contracted and finally pupate. An original drawing of a last instar larval form is appended as Figure 1. Table 1 gives Brindley's measurements of *Tribolium* larvae.

The pupae of *Tribolium* are naked and, with the occasional exception of a slight abdominal movement, they are inactive. They are whitish-yellow when first formed

but turn yellowish with age, being brown at the time of emergence. Brindley finds the pupae have a mean length of 3.46 mm., and a width of 1.12 mm. There is a tendency for the female pupae to be longer than the male. A question of great practical importance for experimentalists working with *Tribolium* is the method of determin-

appendages which are reduced to indistinct elevations in the male. Figure 2 brings out this distinction between the two sexes.

Marshall (1927) has described the development of the compound eye of *Tribolium confusum*, and, since this is a contribution to the metamorphosis of these beetles, it is considered wise to outline the essentials of this development here. The compound eye makes its first appearance in a late larval instar as a grouping together, in the eye regions, of a few hypodermal cells to form a spindle-like body. These cells are the visual cells and by increasing in size they form the retinula. At the distal end of this retinula four nuclei enlarge and, with their surrounding cytoplasm, become the crystalline cone cells. With development there is an increase in the size of these four cells and they eventually become the largest part of the ommatidium. In their growth they push the distal portion of the retinula away from the eye surface. At this stage there have been formed two distinct parts to each developing ommatidium: a proximal portion consisting of the retinula, and a distal portion composed of the crystalline cone cells. Pigment is laid down first in the visual cells, then in the corneal cells, and finally in the cells between the ommatidia. Each crystalline cone cell possesses a large clear space in its proximal part which is an anlage of the crystalline cone. In *Tribolium*, however, this cone disappears during the pupal period and is absent from the eyes of adult beetles. Early in its development each ommatidium becomes convex over its exterior surface and pushes out the cuticula covering it. This is the start of the cuticular lens. The cells of the cornea lying between the ommatidia secrete cuticula which moves inwards to the crystalline cone cells and forces them from their original position. With this secretion of cuticula the lens development is completed.

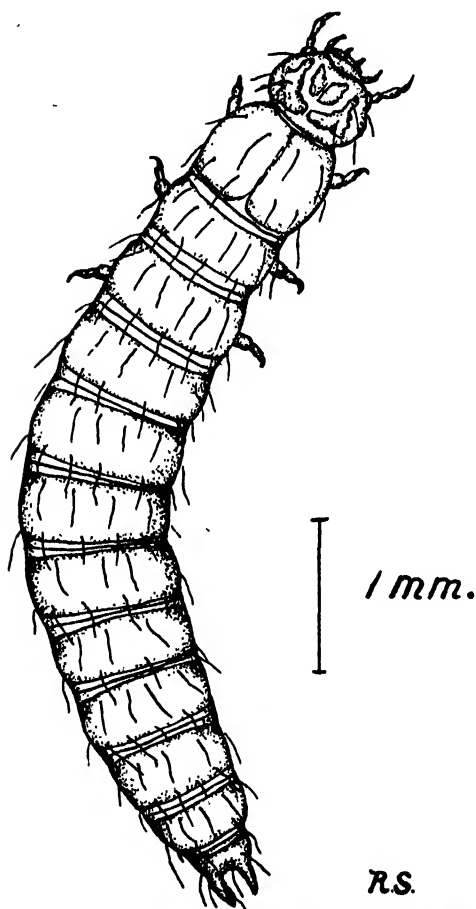


FIG. 1. DRAWING OF A LAST INSTAR LARVAL FORM

ing the sex of the beetles. As far as is known, the only reliable external sexual characteristic for any stage is found in the pupal stage. When the ventral posterior ends of the male and female pupae are examined under low magnification this sexual distinction is obvious. On the terminal segment the female has a pair of small

A good idea of the proportions of *Tribolium confusum* adults may be obtained from Figure 4. Brindley records their mean length as 3.4 mm., width across the thorax 1.02 mm., mean male weight 1.48 mg., and mean female weight 1.78 mg. There seems to be a quite consistent tendency for the females to be larger than the males but there are enough exceptions to this fact to prevent the size of the adults from being used as a reliable criterion of sex. Immediately after emergence the chitinous exoskeleton of the adult beetle is soft; the

four months. The present author has observed that the majority of individuals which successfully emerge and meet with no accidents live at least six months. This long life is, of course, frequently valuable from the viewpoint of the experimentalist.

Brindley (1930) has reported on the life cycle of *Tribolium confusum* under carefully controlled conditions of humidity and temperature. This author subjected the beetles to a temperature of 29.7° C., and a relative humidity of 73 per cent. His findings,

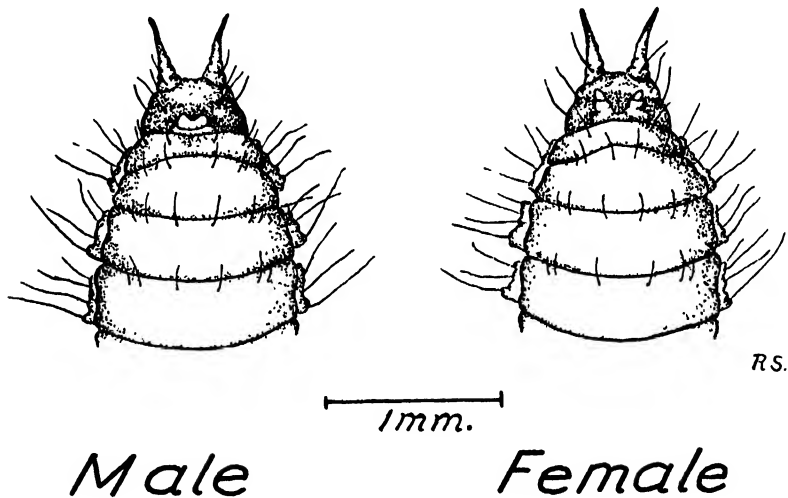


FIG. 2. TERMINAL VIEW OF MALE AND FEMALE TRIBOLIUM PUPAE SHOWING THE SEXUAL CHARACTERS

forms are inactive, and are a light brown in color. In one or two days, however, the beetles have assumed the typical reddish-brown color with the exoskeleton quite hard. In very old *Tribolium* the adults are nearly black. Good (1933) reports observations on the longevity of adult *Tribolium*. This investigator observed 50 individuals and found 13 of them alive after 24 months of life. Dr. Good has informed the writer that of these 13, one male lived approximately three years nine months, another male three years eight months, and a third male three years

as to the duration of the various stages, are recorded in Table 2. These data bring out the fact that all of the larval stages are passed through rather rapidly except the last instar which is comparable in extent to the egg and pupal periods. As indicated by the standard deviation this last larval instar also displays the greatest time variation in its duration. It is interesting to note that this is related to the observation of Chapman (1918) who points out that the last larval instar is more influenced by ecological changes, with respect to its duration, than any of the other

developmental stages. The average length of time required for the completion of a *Tribolium* life-cycle under Brindley's conditions of temperature and humidity, and food is 30 days. These data of Brindley's demonstrate that for a particular set of conditions, and a presumably in-bred stock, the variation in the length of the cycle is surprisingly small for observations based on 100 different individuals. It would be erroneous to generalize, however, that 30 days represents the usual length of the cycle. Good (1933), to illustrate, shows that the length of the cycle varies, for one

adults spend the winter in unheated Maryland flour mills in a semi-dormant condition, resuming breeding as the spring approaches. The larvae and pupae do not seem so able to withstand low temperatures as do the adults. Chapman (1931) reports that *Tribolium* adults die in a few weeks if subjected to a temperature as low as 7°C., indicating their inability to assume a true dormancy. On the basis of experimentation (Chapman, 1931; Chapman and Baird, 1933; Stanley, 1932) the relation of temperature to the length of the life-cycle can be summarized as follows: at 32°C., the development from egg to adult is passed through in about 27 days; at 27°C., in about 37 days, and at 22°C., in about 93 days. These figures were all obtained under constant conditions of humidity (75 per cent) with whole wheat flour used as food.

An essential point to be emphasized about the life-cycle of *Tribolium confusum* is that it must be expressed relative to the specific environmental conditions obtaining at the time of observation. Although no actual data are available as yet it is most probable that the duration of metamorphosis also varies according to the genetic pattern of the beetles as well as with the surrounding ecological conditions.

Holdaway (1932) has reported at length upon the effects of atmospheric moisture on *Tribolium*. This author deals with the following aspects of the subject: first, the effect of humidity on the size of adult populations; second, the rate of population growth as related to humidity; third, the effect of change of humidity on population equilibrium; fourth, the relation of humidity to the rate of development and the viability of the various metamorphic stages, i.e., physiological effects of humidity, and last, the importance of humidity in affecting entire populations. Holdaway finds adult *Tribolium* increase in numbers as the humidity increases from 25 per cent to

TABLE 2

Length of the stadia of *Tribolium*. (Taken from Brindley by permission of the Ann. Ent. Soc. Amer.)

STAGE	LENGTH OF STAGES (IN DAYS)			
	Minimum	Maximum	Average	Standard deviation
Egg.....	5.5	5.5	5.5	0.00
1st. instar.....	2.0	2.0	2.0	0.00
2nd. instar.....	2.0	3.0	3.0	0.05
3rd. instar.....	2.0	3.0	2.5	0.68
4th. instar.....	2.0	3.0	2.7	0.55
5th. instar.....	2.0	3.0	2.8	0.36
6th. instar.....	5.0	7.0	5.5	0.71
Pupa.....	6.0	7.0	6.2	0.44
Totals.....	26.5	33.5	30.2	

thing, according to the food the larvae feed on. At 27°C., this writer finds that the larval period lasts 31 days when the forms had been reared on middlings as compared to 89 days when the larvae had been raised in white flour. The latter observation differs from the experience of the present author, however, since, in white patent flour at a temperature of 28°C., and a relative humidity of approximately 50 per cent, an entire life-cycle from egg to adult is completed in about 50 days. The cycle becomes longer as the temperature lowers. Good reports that *Tribolium*

75 per cent. In his experiments there were 9.5 beetles per gram of flour at 25 per cent R. H., 11.4 beetles per gram of flour at 50 per cent R. H., and 15 per gram of flour at 75 per cent R. H. Above 75 per cent the number of adults declines due to the development of fungus in the flour. The author also noted that the adult populations kept at 75 per cent R. H. had a faster growth rate than those at lower humidities. By taking, for example, an asymptotic population of adult beetles characteristic of a 25 per cent humidity environment (9.5 beetles per gram of flour) and subjecting this same group to a humidity of 75 per cent the population assumed the concentration typical for a 75 per cent humidity (15 beetles per gram of flour). This indicates that the effects of humidity on the life-cycle are probably not irreversible in nature. In studying the relation of humidity to viability of immature stages Holdaway found that, in general, more eggs hatched in low humidities than in high. On the other hand, the larvae showed a greater survival in the high humidity environments with the optimum at 75 per cent. The pupae had coefficients of survival similar to those of the eggs since more pupae failed to develop as the surrounding atmospheric moisture increased. A consideration of the effect of humidity on rate of metamorphosis showed that the eggs and pupal stages were little influenced by humidity conditions while the larvae developed more rapidly as the humidity increased from 25 per cent to 75 per cent. Holdaway investigated the influence of 25 per cent, 50 per cent, and 75 per cent relative humidity on oviposition and concluded that no apparent effects were discernible. A further statistical analysis of his data (Table XV, p. 296), however, suggests that the fecundity rate is significantly higher for beetles in a 50 per cent humidity environment when compared

with those in 25 per cent. The females in 75 per cent humidity also produced significantly more eggs than those in 25 per cent. When the females of the 50 per cent environment were compared with those in the 75 per cent environment there was a suggestion (1.9 times the standard error) that the former were ovipositing more rapidly. The effect of humidity on oviposition can not be considered definitely closed at the present time.

As an elaboration of the life-cycle of *Tribolium confusum* it might be well to describe briefly some of the facts known as to the growth of entire populations of these forms. Chapman (1928) has experimentally approached this problem with interesting results. This author set up six environments of whole-wheat flour which increased in size geometrically. The environments consisted of 4, 8, 16, 32, 64, and 128 grams of flour. Adult *Tribolium* were introduced into these environments to provide initially one beetle to each two grams of flour. Thus the four gram culture contained one pair of *Tribolium*, the eight gram culture two pairs, the 16 gram culture four pairs, the 32 gram culture eight pairs, the 64 gram culture 16 pairs, and the 128 gram culture 32 pairs. Counts of the number of eggs, larvae, pupae, and adults were made at various intervals in order to see how the total population was increasing relative to environmental size. The essential point of the data, as emphasized by Chapman, was that after a period of approximately 100 days the populations all reached an equilibrium which was similar for all the environments when measured in terms of beetles per gram of flour. In other words, the culture of 128 grams of flour with its initial population of 32 pairs of beetles, although much larger after 100 days in terms of total number of individuals, contained essentially the same number per gram of flour as did, for

example, the 4 gram-1 pair unit. Chapman calculated this equilibrium point attained by *Tribolium*, under these specific conditions of temperature, humidity and kind of flour, to be 43.97 ± 2.88 individuals per gram of flour. Chapman con-

since, although thousands of eggs may be present in the environment at any one time, only some of them escape being eaten. It is this eating of eggs, which is directly proportional to the population concentration, that maintains the equilibrium of

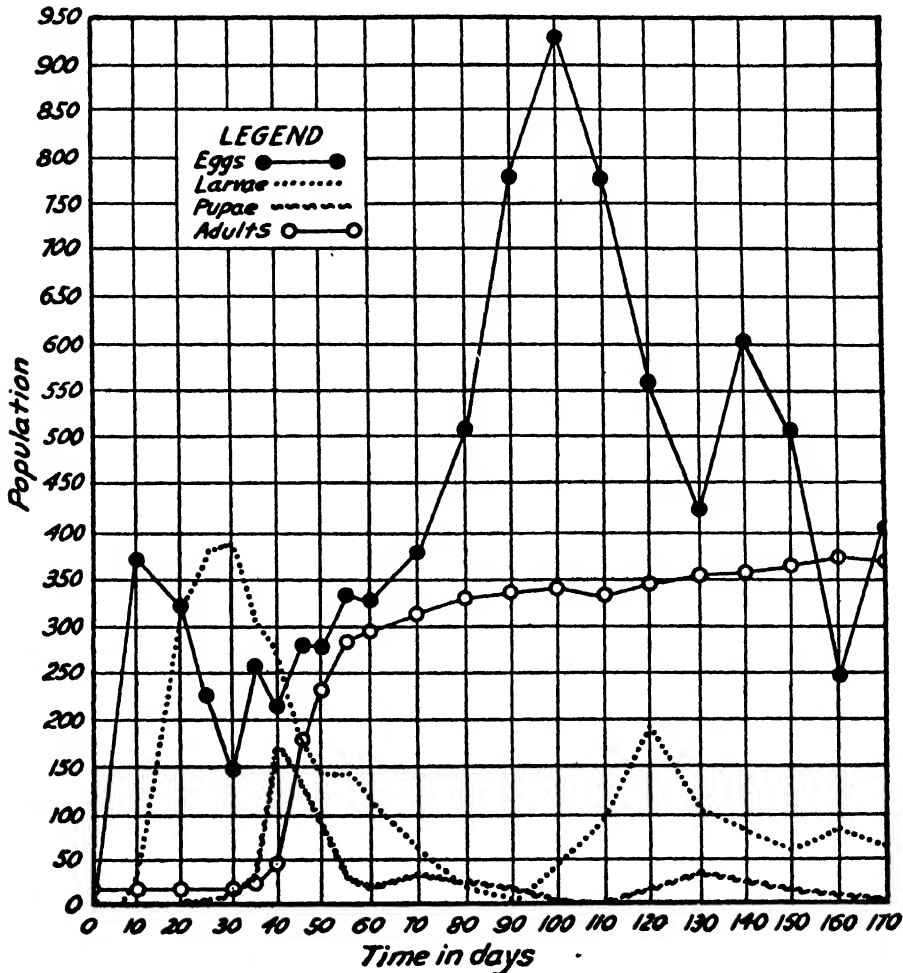


FIG. 3. POPULATION GROWTH OF *TRIBOLIUM CONFUSUM* AT 27°C., AND 75% RELATIVE HUMIDITY (Taken from Stanley, 1932, Canadian Journal of Research, 6, p. 668, by permission)

siders this equilibrium to be the result of the interplay between the capacity of the species to reproduce (Biotic Potential) and the resistance of the environment. The author concludes that cannibalism is a most important factor in this resistance

the total number of individuals. Nicholson (1933: p. 140) criticizes Chapman's method of calculating 'environmental resistance' as follows:

... Having experimentally determined the density of *Tribolium confusum* under certain conditions, he pro-

ceeds to calculate environmental resistance by means of his formula. A glance at this example (p. 120) shows that the only use made of the experimentally determined density is to multiply *both* sides of the equation by it. Clearly the result is independent of density, and Chapman's hypothesis completely fails to deal quantitatively with animal populations.

Gause (1931) analyzed the data of Chapman and showed that the *Tribolium* populations grew according to the well-known logistic curve of Verhulst (1838) and Pearl (1925). Figure 3, taken from Stanley (1932), shows the varying numbers of eggs, larvae, pupae and adults present in active *Tribolium* populations incubated at 27°C., for a period of 170 days. Chapman (1933), in a pre-publication abstract, calls attention to the fluctuation of numbers in *Tribolium* populations. This investigator has carried on four separate populations for nearly two years and has demonstrated a synchronous fluctuation of their numbers.

Allee (1931, 1934), Maclagan (1932), and Park (1932, 1933) have shown that in early stages of population growth there may be an optimal population size for growth which is larger than the initial minimum beetle concentration and smaller than the initial maximum beetle concentration. Allee has related these observations to the beneficial effects frequently resulting from crowding. Maclagan and Park have presented analyses as to the casual factors involved with a discussion of these two theories by Park (1934).

PRODUCTIVITY

One aspect of the general biology of *Tribolium confusum* of obvious importance to experimentalists is the question of productivity. This can be interpreted as dealing with both oviposition, or fecundity, and fertility, or percentage of egg hatch. It is only recently that data have been reported on these considerations and much still remains to be done. Good (1933)

reports a series of interesting observations on oviposition which are valuable since they record the number of eggs produced by females during the entire period of their egg-laying life. This period, according to Good, may last as long as 14 months, the average being approximately nine months. During this time a female *Tribolium* normally lays 400 to 500 eggs, although records of nearly a thousand eggs are not unknown. With regard to egg fertility Good reports that about 90 per cent of these eggs hatch. Brindley (1930) obtained oviposition data for ten newly emerged *Tribolium* pairs and found, as might be expected, that these young females oviposited at a much higher rate during this limited period than did the forms used by Good who obtained long-time records. Using Pearl's (1922) 'rate per female per day' method of measuring fecundity, Brindley reports, for this ten day period, an average of about 11 eggs per female per day with occasionally as high as 18 eggs being produced in a single day. These rates are higher than those of Chapman (1918) or Park (1932, '33) who also worked with young females over a short period of observation. One reason for this discrepancy is undoubtedly, as Brindley points out, the fact that he removed his adult beetles daily and introduced them into fresh flour thus essentially eliminating the eating of eggs by adults. In addition, other factors, both genetic and ecological, are quite conceivably operating in this case. As a general example, temperature has been demonstrated to affect oviposition. Stanley (1932) summarizes certain data of Chapman on the effect of temperature on egg-laying. At 22°C., the mean oviposition rate per female per day was 1.9 eggs; at 27°C., 6.24 eggs, and at 32°C., 10.73 eggs. These are all significant differences and clearly indicate the relation of moderate temperature varia-

tions to fecundity. Park (1932, '33), in studying population problems, had occasion to repeat frequently a standard experiment in which either one pair of young adult *Tribolium* or else a single fecundated female spent eleven days in 32 grams of patent flour at 28°C., with egg counts made at the end of that time. As a further contribution to the question of *Tribolium* productivity all cases falling within the above experimental type have been collected from the data of both papers and are biometrically presented in Table 3. These rates are, on the mean, slightly higher than those presented by Good but much lower than those of Brindley and Chapman as

TABLE 3

Egg productivity rates of Tribolium confusum (237 cases calculated from the data of Park, 1932, '33)

Maximum number of eggs after 11 days incubation.....	63. eggs
Minimum number of eggs after 11 days incubation.....	0.
Mean number of eggs after 11 days incubation.....	38.9 \pm .64
Median number.....	31.2 \pm .80
Standard deviation.....	14.8 \pm .45
Coefficient of variation.....	38% \pm 1.17
Mean rate per female per day.....	3.5

reported by Stanley (1932). It should be emphasized that in these experiments no attempt was made to eliminate cannibalism: the rates presented here are not therefore *sensu stricto* absolute fecundity rates but simply measure the eggs remaining in the population after some have been consumed. The emphasis here was placed upon the study of natural populations in which egg-eating is an important function. Park used patent flour in his experiments while Chapman and Brindley used whole-wheat flour. Good (1933) has shown that the kind of flour influences egg laying. At 27°C., in whole-wheat flour he found the mean egg rate per female per day was 2.43 eggs; in

bran, 1.26 eggs; in oatmeal, 1.04 eggs, and in white patent flour, 0.58 eggs. There is, in all probability, no real discrepancy between these data and those of other authors since the experimental conditions and procedure have been different with various ultimate aims in mind. On the other hand, there seems to be no patent biological reason why these rates and those obtained by Chapman and Brindley, who worked with different stocks and in a different location, should necessarily closely approach the same constant figure. This argument is further substantiated by the investigations of Good (1933) who obtained oviposition rates much lower than those of Chapman. It should be indicated that Good purposely ran his experiments over a long period of time and the rates he obtained may have been influenced by aging on the part of the beetles. On the other hand Good removed the adults from their flour daily so that egg-eating effects were minimized. About oviposition Good says, "The number of eggs laid per day is not large. In no case were more than 13 viable eggs laid in one day by a single female, and the average was only 2 or 3 per day. Under optimum conditions Brindley records 18 eggs in one day and a much higher daily average than is indicated here." (p. 330)

As can be seen from the standard deviation of Table 3, these particular egg-rates of *Tribolium* vary considerably between individuals even when experimental conditions are quite closely controlled. These data do not, of course, indicate whether the egg-laying and egg survival variation is due to non-controlled ecological factors, or to genetic differences between the beetles. Presumably both types of factors are operating. It is a common observation that one female may have a high oviposition rate which persists throughout a considerable portion of that individual's life, while

another female, under as nearly similar conditions as can be obtained, has a consistently low oviposition rate. Facts such as these seem to indicate that the genetic constitution of the beetle in question is an important factor in fecundity as well as are ecological influences. With respect to egg fertility Park (1933) found that about 90 per cent of the eggs produced larvae providing they were laid by a female who had experienced more than a single initial copulation. Park also reported the oviposition rate of young virgin *Tribolium* females showing it to be much lower (about 20 times) than that of fecundated individuals.

An interesting, but anticipated, feature of *Tribolium* oviposition is that it is affected by certain environmental influences such as kind of flour, possibly humidity (Holdaway, 1932), temperature, conditioning of the flour by beetles living in it (Park, 1934), as well as population density relationships. Facts such as these where such a major function as reproduction can be shown to be sensitive to experimental changes enhance the value of the form for study. More work on this general subject seems forthcoming judging from advance abstracts presented by Chapman (1933) and Chapman and Baird (1933).

CERTAIN ASPECTS OF TRIBOLIUM BEHAVIOR

Certain observations on the behavior of *Tribolium* may be of interest. From common laboratory experience it is obvious that the adults are photo-negative: i.e., they loosely cluster in shaded portions of a container when subjected to direct light. In connection with their behavior to light it is instructive to know that *Tribolium* cultures can be maintained indefinitely in complete darkness as Chapman (1931) has noted. These beetles also react negatively to gravity and when located on a nearly vertical surface crawl to the top of the container. This gravity reaction

seems to be markedly displayed, however, only when the beetles are not located in some kind of solid culture medium. In the latter medium the tendency to vertical stratification, at least in small environments, is slight.

In moving through the flour the beetles seem to employ only trial and error methods since their movement appears quite at random. This fact is possibly implied in the common name of the form, the 'confused' flour beetle, and has been observed a number of times. Stanley (1932, 1932a), working with *Tribolium* populations mathematically, makes the random movement one of his fundamental premises. Park (1933) has shown how the adults of a single colony of *Tribolium* were distributed entirely at random. This type of movement seems to be the logically expected one since such an environment as flour would probably limit the efficient operation of such senses as visual and olfactory. This is substantiated by Chapman's (1931) observation that *Tribolium* exhibits relatively little olfactory selection of food. Although all the evidence points to complete random movement by *Tribolium* in flour, at this stage, however, it can not be too dogmatically asserted that the beetles never exhibit any directed motion.

The fact that adult and larval *Tribolium* practice cannibalism has been reported by several authors. It is known that eggs, early instar larvae, and pupae are consumed. Chapman (1928) emphasized the importance of the egg-eating behavior in the maintenance of population equilibrium. Park (1933) experimentally obtained egg-eating rates by introducing a single adult beetle into an environment of 32 grams of flour which contained initially 30 eggs and making counts of these original 30 eggs after 11 days of incubation. It was found that virgin females, fecundated females, and males had a statistically similar egg-eating

rate as tested by this experiment with the mean number of eggs eaten for the period approximately seven per beetle. It is to be expected, of course, that with other types of experiments these rates might change relatively.

Outside of these statistical approaches to the study of cannibalism, however, there seems to have been little done on the observational side. It might be interesting at this point to resort to natural history and describe the behavior of an adult *Tribolium* in the process of eating an egg. It is impossible, naturally, to observe the beetle eating an egg when both are covered with flour. Therefore, an observation container was fitted up which consisted of a petri dish lined with filter paper containing a number of eggs and several adult *Tribolium*. To facilitate the observation of details the whole dish was placed on the stage of a low powered binocular microscope and the beetles examined through this magnification. In this dish the beetles move at random without any visible reference to the eggs. They occasionally walk over them or roll them to one side as they move about but seem to engage in no definite preliminaries previous to the actual consumption of the egg. It is not clear exactly which senses are employed in the location of a specific egg which is to be eaten. Presumably both visual and tactile senses aid the beetle in its reaction. In eating the egg the *Tribolium* follows a rather definite behavior pattern. The egg is grasped between opposing surfaces of the tarsal joints of the prothoracic legs with the tarsal claws usually puncturing the egg membrane. While the egg is being thus grasped the prothoracic legs are extended forward so that the femur and most of the tibia of both legs parallel the longitudinal axis of the body and may be partly covered by the head. As a result of this leg movement the part of the egg

proximal to the beetle is brought into contact with the mouth parts. By means of mirrors it was possible to observe the mouthparts in action. The short, horny mandibles seem to function primarily in fragmenting particles from the egg while the maxillae and maxillary palpi aid in this fragmentation and also work the material into the mouth proper aided by the labium and labial palpi. The eating of the egg is facilitated by the fact that upon puncturing the egg membrane the fluid contents coagulate and, mixing with the flour which adheres to the external surface of all *Tribolium* eggs, produces a mixture of sufficient consistency to be handled by a form possessing biting mouthparts. As the beetle consumes the egg the prothoracic legs pull the remaining portion posteriorly so that it always approximately maintains its same position relative to the mouth. The meso- and metathoracic legs usually brace the beetle by extension to the side and back. A general representation of the beetle eating an egg is depicted in Figure 4. It is not the purpose of this description to suggest that the behavior described is a fixed and non-variable one, for this would be fallacious. This report does describe, however, the typical chain of events as they were observed during the reaction. A beetle can completely consume an egg in fifteen minutes, although frequently it may take much longer. Quite often a *Tribolium* may leave an egg before it has been completely eaten. When the observation tray was covered with a thin layer of flour the egg-eating behavior remained unchanged.

Another behavior reaction of probable interest to experimentalists is the copulation one. The importance of copulation in certain *Tribolium* populations has already been reported by Park (1933) where it was demonstrated that, up to a certain point, the fecundity and fertility of *Tri-*

bolium females was increased by repeated copulations. Copulation seems to be a frequently practiced behavior among *Tribolium* as both statistical and observational data show. There do not seem to exist, however, any particularly elaborate or

both as to its extent and nature. Often a male may follow a female and, attempting to mount her with no success, eventually cease his activities. Again the two sexes may meet and copulate without any visible preliminaries at all. In mounting the fe-

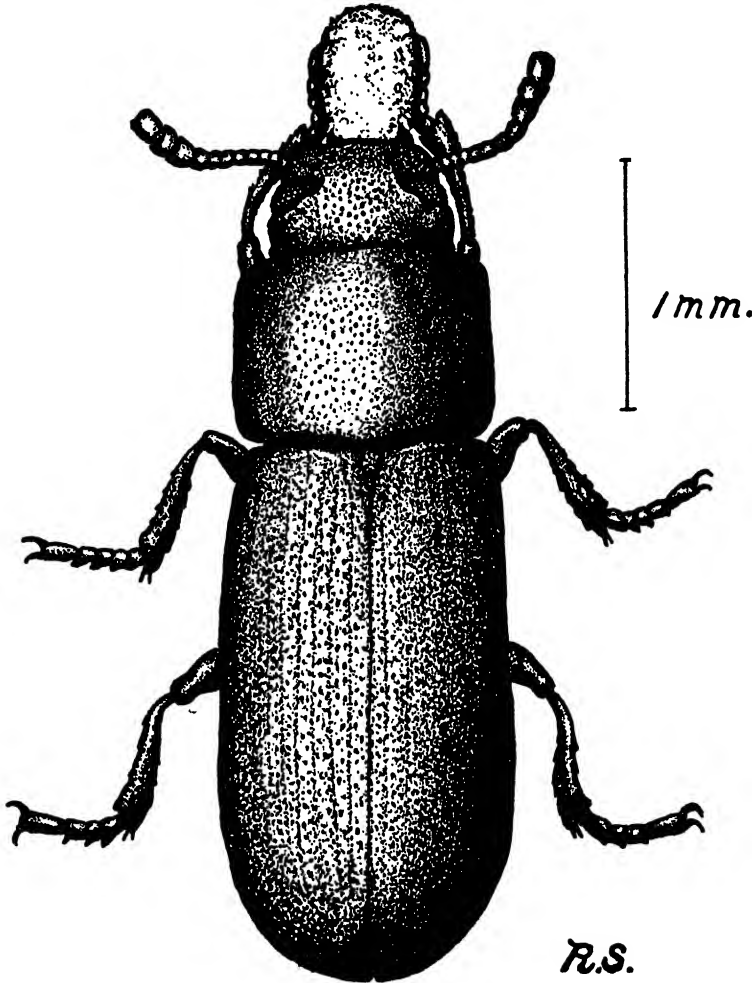


FIG. 4. DRAWING SHOWING AN ADULT TRIBOLIUM EATING ONE OF ITS OWN EGGS (from life)

unvarying behavior reactions associated with the process. Males can occasionally be observed to attempt to mount other males. This suggests that sex recognition is not highly developed among these forms. The pre-copulation behavior varies greatly

male the male beetle clasps her with all three pairs of legs extending them around the ventral surface of her body. The male lies somewhat posteriorly on the dorsal surface of the female so that his head coincides with the thorax of the female. This

allows the terminal end of the male's abdomen to project out behind that of the female. The chitinized penis is then projected downward and forward making contact with the vagina which is but slightly extruded. When this connection has been effected the seminal fluid, a mucous-like, slightly milky appearing secretion, enters the vagina. As far as the author's personal experience is concerned the mating pair may remain united for as long a period as fifteen minutes or, conversely, the copulation may be consummated within a space of two or three minutes time. During the copulation the females are sometimes observed to move about rapidly and at other times to remain motionless. Frequently the male completely withdraws the penis but remains clasped to the female and inserts it again after a varying length of time.

A brief comment might be made about the defecation of *Tribolium* adults. This was observed by means of the same type of observation apparatus used in studying cannibalism. Defecation seems to be a rather frequent process judging from the accumulation of fecal matter on the filter paper. The feces are well formed, ovoidal in shape, and vary in color from almost colorless, through various degrees of green, to a dark black. The beetles observed had all been fed upon patent flour. In defecating a single pellet is usually extruded. In the cases observed this is rather quickly done. The beetles may defecate either while moving or quiescent.

Another behavior reaction may be mentioned since, although infrequent, it is of considerable biological interest. Chapman (1926) noted that when aggregated *Tribolium* adults were stimulated by rubbing they emitted a rather pungent gas, "... which smells not unlike an aldehyde. It irritates the mucous membrane of the nose and turns flour and certain other materials pink, and in high concen-

tration, affects the eyes." (p. 295) When the larval and pupal forms of *Tribolium* were subjected to the gas Chapman observed that in about 10 per cent of the cases abnormal forms were developed. The mature larvae emerged with a combination of larval and pupal structures and the pupae emerged as adults displaying some deformity. Chapman concludes that the development of these monsters is associated in some manner with the gas produced by the beetles when the latter are irritated by some unusual stimulus. The control larvae and pupae not subjected to the gas showed no incidence of this atypical metamorphosis. Doctor John Stanley (personal communication) has advised me that there is some evidence that the gas, along with certain fluids found in *Tribolium*, may be irritating to man resulting particularly in gastric disorders. He advocates discretion in the handling of the form for this reason.

Adult *Tribolium confusum* possess fairly well developed wings which leads to the question concerning their ability to fly. Good (1933) reports that he has never observed *Tribolium confusum* fly or even attempt flight. According to this author, however, the closely related species, *Tribolium ferrugineum*=*castaneum*, frequently attempts to fly and, when stimulated by a strong light, occasionally makes short flights of a few feet. Holdaway (1932) reports that on one occasion only has he observed *Tribolium confusum* fly and that was when the form had been stimulated by high temperature. The present author has never observed flight on the part of these beetles.

Adult *Tribolium* frequently practice death-feigning or letisimulation. In handling the beetles the author has often observed them draw in the legs and remain completely quiet despite the fact they were being moved about. This reaction is of short duration, however, a few seconds

at the most, and the forms soon become active irrespective of outside stimulation.

TRIBOLIUM PARASITES

Good (1933) reports the occurrence of two mites *Acarophenax tribolii* Newstead and Duval and *Pediculoides ventricosus* Newport, and a bethylid (parasitic wasp), *Rhabdopyris zeae* Waterston as parasitic on *Tribolium*. This author states that these three forms are not very effective in controlling the beetles. Doctor Clay G. Huff, of the University of Chicago, and the present author studied a case of internal parasitism in *Tribolium confusum* which arose in the stock cultures. The parasites seemed to have their effect upon

used. Standard glass battery jars about 25 x 19 cm., are convenient and economical and may be stacked in incubators with a minimal loss of space. Many kinds of food can be used for breeding the beetles and most of the *Tribolium* workers seem to have favored whole wheat flour. Since the wheat husks so frequently resemble the larvae and since they (the husks) do not pass through fine meshed sieves it is advisable to use a flour which has these seed-coats removed. The present author uses 'Ceresota' a non-bleached, commercial, white patent flour. It is preferable to keep the stock jars in constant temperature incubators at a temperature between 27°C. and 30°C. The humidity can either be

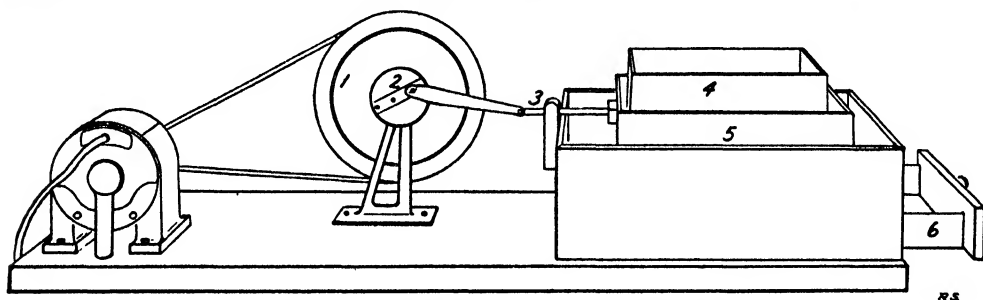


FIG. 5. DIAGRAM OF THE AUTOMATIC FLOUR SIFTER

1, belt wheel; 2, driving wheel; 3, driving rod; 4, flour sieve; 5, flour sieve holder; 6, removable collecting tray

the pupal stages since the latter, when parasitized heavily, grew dark in color and failed to emerge as adults. Histological preparations were made of the pupae and the parasite studied. The conclusion was reached that this form was a coelomic coccidian probably belonging to the genus *Adelina* and previously referred to by Riley and Krogh (1922) and White (1923). The latter writer mentions that infected larvae and adults, as well as pupae, frequently die of the disease. Gregarines are also reported as infesting *Tribolium confusum*.

TECHNIQUE

In culturing stock *Tribolium* populations practically any type of receptacle may be

accurately controlled or may be allowed to vary between 40 and 75 per cent. In order to maintain the stocks at asymptotic concentration it is necessary to change the flour frequently as Park (1934) has demonstrated.

A census can be taken of infected flour by passing it through fine meshed standard silk bolting cloth. Chapman (1918) used different meshed cloths and found that number 9, for example, would not pass any of the *Tribolium* stages but would permit finely milled flour to go through; number 3 separated eggs and larger larval stages from the flour; number 000 passed all eggs and larvae except the last instar forms, etc. Thus by using bolting cloth sieves of a specific mesh *Tribolium* stages may be re-

tained for counting as desired. To facilitate the sieving of the flour the author uses an electrically driven sifting apparatus constructed for him by Mr. M. E. Carson, Whitman Laboratory, University of Chicago. This apparatus (Fig. 5) simply moves a framed piece of bolting cloth back and forth over a removable tray and separates the desired beetle stages from the flour which collects in the tray below. There is evidence to show that shaking affects adversely the oviposition of adult *Tribolium* (Stanley, 1932). For this reason, it is desirable to gently remove the adult beetles from the experimental flour before sifting is started. The beetles may be handled with brush or spatula.

SUMMARY

The twofold purpose of this paper has been to point out the desirable features exhibited by *Tribolium confusum* Duval for experimentation, and to present information about the general biology of the form which might be useful to present and future

investigators. At the present time most of the *Tribolium* experimentalists are using the flour beetle in population studies. This is, of course, easily understood since the form is admirably suited for studies of this type due to the homogeneity and reproducibility of its environment. Many population problems remain to be solved here, however, and future work is to be encouraged. On the other hand, *Tribolium* does not seem limited to population studies alone; investigations on nutritional, radiation, behavior, metamorphosis, and possibly genetic problems can be approached by the use of this organism.

The author wishes to make certain specific acknowledgements of assistance rendered in the preparation of this paper. To Professors Raymond Pearl and W. C. Allee I am deeply indebted for their critical treatment of the manuscript. I am also indebted to Doctor Orlando Park, of the University of Illinois, for pertinent citations, and to Doctor R. G. Schott for his efficient preparation of the text figures. My thanks are due Doctor Newell Good, of the Department of Agriculture, for advice and permission to use unpublished material. It is indeed a pleasure to make these acknowledgements.

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A PHYLOGENETIC ASPECT OF THE MOTOR CORTEX OF MAMMALS

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FOREWORD

THE following paper was left in manuscript form by my colleague, the late Dr. Ernst Huber. A greatly condensed and abbreviated digest has already appeared (in chapter III of "Evolution of Facial Musculature and Cutaneous Field of Trigemini. Part I," *QUARTERLY REVIEW OF BIOLOGY*, vol. 5, pp. 133-188, 1930). Dr. Huber had intended that, before publication of the present contribution, he would include full discussions of the corticospinal tract in the various mammalian groups, but this plan was never completed. As it stands, the paper is practically as written by Dr. Huber, although I have made certain changes that seemed desirable. I have also attempted to include some of the more recent literature dealing with the motor cortex, and am entirely responsible for the discussions of those investigations published since 1929. The part dealing with man was lost by Dr. Huber and has been rewritten by me in accordance with notes left by him. I have taken the liberty of inserting synonyms for the various primates discussed at the proper places in the text; these may be of value to the reader in fully identifying the forms studied. Figures 1, 2, 7, 8, 10, 11, 12, 17 and 19 were drawn by Dr. Huber and published in his aforementioned paper, and they are reprinted here in slightly altered form. The remaining figures have been selected from the literature by me and have been most kindly redrawn by Mr. James F. Didusch. I am entirely responsible for the figure explanations, as well as for the brief "Introduction." It should be mentioned that the discussion of the motor cortex, as defined in this paper, does not include those stimulative areas of the frontal and occipital regions which give rise to ocular movements; these centers differ histologically from the immediate precentral motor area and hence fall into a separate category. No systematic discussion of the cyto-architecture of the cortex has been attempted, but references are made to this phase of the problem wherever they seem pertinent. WILLIAM L. STRAUS, JR., Feb. 21, 1933.

INTRODUCTION

A specialization within the telencephalon to form a "motor cortex" is an attribute

of the mammalian brain. The formation of such an area is foreshadowed in reptiles (alligator: Johnston, 1916; Bagley and Richter, '24; Bagley and Langworthy, '26; turtles (*Chelydra*, *Chrysemys*, *Cistudo*): Johnston, '16; lizard (*Gerrhonotus*): Johnston, '16) and birds (pigeon: Rogers, 1922/23), at least some of which possess electrically excitable cortical areas. In these forms, however, the axons of the stimulative cortical cells do not form a corticospinal tract. This tract is found only in the mammals (Kappers, 1920). The "motor cortex," as defined in this paper, is that cortical area or areas giving rise to such a direct pathway to the various body levels. Hence a discussion of this system is necessarily limited to mammalian forms. The present paper attempts to bring together the existing knowledge concerning the motor cortex in the various orders of mammals, with a view toward demonstrating its phylogenetic development.

1. DIFFICULTIES OF CORTICAL STIMULATION

Since the epoch making pioneer work of Fritsch and Hitzig (1870) a vast amount of data from studies on the motor cortex of the brain in a number of mammalian types (monotremes, marsupials and placentals) has been accumulated. The extensive literature on this subject is, however, of very unequal value. Unfortunately, numerous errors have often been carried over into later publications.

In spite of the fact that Fritsch and Hitzig used galvanic current with bipolar stimulation, their first delineation of the motor

cortex was remarkably accurate. Ferrier (1873) introduced the faradic current as being preferable to the galvanic stimulation of the cerebral cortex. Though his results were far less accurate than those obtained by Fritsch and Hitzig (1870) and Hitzig (1873, '74, 1904), the new method eventually proved superior to the old. It was generally accepted and made possible a decided advance.

Much of the success of cortical stimulation depends upon proper anesthesia and application of moderately weak current. No definite result can be expected when animals are too deeply anesthetized, because under such conditions the strong current necessary to elicit movement may spread into areas adjacent to that under direct stimulation. Many of the incorrect and unreliable statements in the literature are obviously the result of such faulty technique. Ferrier, working on adult animals, and using a very strong current, scattered the motor areas over almost the entire lateral surface of the cortex. Partly because of the same reason, a series of succeeding authors obtained scarcely more accurate results.

It is essential to realize that the strength of current necessary to elicit movements in the newborn and in animals in the very first stages of postnatal life is greater than that required to produce movements in adults of the same species. As the animals grow to maturity the threshold for the excitability of the motor cortex gradually becomes lower. Leyton and Sherrington (1917) reported comparative data from cat, macaque and chimpanzee, animals which are known to give ready and consistent response. These three types were stimulated side by side under the same conditions, and were found to be similarly responsive. Yet from a comparison of the results which the various investigators obtained in stimulation experiments on many representatives of the various orders and suborders of mam-

mals, it is seen that apart from those differences in the excitability of the motor cortex which are due to variable factors in connection with the experiments (e.g. condition of the animal, condition of the brain, depth of narcosis, etc.), there appear to exist additional consistent differences presumably dependent upon dissimilarities in structure and function of the motor cortex of various mammals. Thus mammals with primitively organized brains require stronger current than those with more highly organized motor cortexes. Likewise, the strength of current necessary to elicit movements varies in regard to the different centers of the motor cortex of the same animal. Because of these various conditions a keen judgment, gained only by much experience, is necessary for the application of the proper optimal current.

Furthermore, if one critically analyses the records of bilateral and ipsilateral responses, he must conclude that possibly many of them were the result of spread of current along the dura mater to cranial and upper spinal nerves of the side under stimulation. In some instances, however, especially in mammals with a primitive central nervous system, such bilateral and ipsilateral responses may have an anatomical basis in the incomplete crossing of the corticospinal tracts. In other instances, however, as in part of the facial musculature, bilateral response with prevalence of the contralateral side appears to be due to bilateral cortical representation of certain muscle groups which normally give purposeful automatic movements of the ipsilateral side associated with movements of the contralateral side (synkinesis). Such bilateral cortical representation is evidently confirmed in some instances through ablation experiments, e.g. in the case of the m. orbicularis oculi of the chimpanzee (Grünbaum and Sherrington, 1904).

On the other hand, animals have often

been stimulated under too light anesthesia or without any anesthesia whatever. Under such conditions, movements occurring spontaneously in the animals and not the result of electrical stimulation have frequently been recorded together with the movements resulting from actual stimulation. Some examples of such errors which are scattered throughout the literature are pointed out in the following pages. For an experienced and critical investigator it should be possible to discriminate between the two kinds of movements, especially in adult animals, because each has its characteristic attributes. If an investigator has acquired this discriminating judgment he may in certain instances obtain more complete results without the use of anesthesia (compare e.g. results of stimulation experiments on newborn and very young animals).

The application of pharmacological agencies for increasing the local excitability of the motor cortex may likewise at times have led to false impressions.

The introduction of the unipolar method by Sherrington (1893) brought about a considerable improvement in cortical stimulation. This method makes possible a more accurate localization. It has proved to be of greatest importance in investigations of highly organized brains with a highly differentiated and much subdivided motor cortex. Occasionally, nevertheless, more recent investigators have preferred the bipolar to the unipolar method, with fair success in lowly mammals (e.g. Rogers, 1924, on the opossum).

As a whole, the results obtained by the different authors are proportionate to application of proper methods, careful operative technique, good condition of the experimental animal, proper care of the exposed cortex, accuracy of observation, discriminative judgment and a series of other factors.

The results so far at hand are as yet little correlated with the genealogy and be-

havior of the animals investigated. A vast amount of data concerns merely the determination of the extent and location of the responsive motor areas and of their subdivisions. Yet even in regard to the topography of these areas relatively few mammalian types are satisfactorily known.

II. THE ONTOGENETIC DEVELOPMENT OF THE MOTOR CORTEX

The facial area has been only roughly determined in connection with the general investigations on the motor cortex. From these investigations it becomes evident that the motor facial area was one of the first during the phylogeny of mammals to become definitely localized in the cerebral cortex.

During the ontogenetic development of certain mammals, however, the facial area becomes responsive to electrical stimulation at a considerably later stage than does the fore limb area. This is clearly shown through the important contributions of Weed and Langworthy (1925) and Langworthy (1927a). Using the opossum (*Didelphys virginiana*) as an experimental animal, these investigators stimulated various stages of pouch-young, which correspond to early fetal stages of placental mammals. Already at the early age of 23 days (crown-rump length, 33 mm.), the youngest stage used in the experimentation, fore limb movements were obtained upon cortical stimulation, while no other areas responded.

Through the observations of Hartman (1920), it has become known that after the 10 day gestation-period the very immaturely born young, measuring only 11 mm. in crown-rump length, crawl, without any assistance from the mother, from the vaginal orifice to the pouch, where they quickly become attached to the nipples. In crawling they use the fore limbs, swaying the head as far as possible to the side opposite the hand which is taking

the propelling stroke. While the fore limbs already are used at this early embryonic stage in such an important function, the hind limbs are represented merely by extensive buds. The kangaroo young reaches the pouch of the mother in the same manner as does the opossum (Hartman). In their structural and functional development the fore limbs precede the hind limbs, not only in the polyprotodont marsupials, which in the fully developed stage have fore and hind legs of corresponding size, but likewise in the more specialized diprotodont marsupials, not excepting the big kangaroos with their exceedingly large, strong hind legs and contrastingly small, short fore legs. It was not until the stage of 76 day old pouch-young opossums of 127 mm. crown-rump length that Weed and Langworthy obtained movements from centers other than that of the fore limb. Additional responses were then procured from the facial-masticatory muscle complex. The facial area responded with movements of the vibrissae, ear and eye. In view of the precedence in structural development and early use of the forelimbs, and taking into consideration some further significant points, the author concludes that the considerably earlier response from the fore limb area in contrast to the facial area in the opossum, is due to a developmental adjustment and not, as Langworthy (1927a) suggested, to a phylogenetic sequence. No hind limb movements were obtained from any stage of opossum young, nor from a larger series of adult opossums (Weed and Langworthy, 1925; Langworthy, '27a).

Similarly, as in the opossum, in certain representatives of the placentals the fore limb area has been found to be responsive before the facial and hind limb areas. A series of investigators (Soltmann, 1876; Tarchanoff, '78; Paneth, '85; Langlois, '89; Mills, '94, '95, '96; Michailow, 1910; v.

Bechterew, '11; Weed and Langworthy, '26; Langworthy, '27b; and others) have studied the electrical excitability of the cerebral cortex of newborn and very young placentals, using cats, dogs, rabbits and guinea-pigs as experimental animals. The findings of the various authors differ greatly, however.

Mills (1896) found that at birth and for several days after the cortex of cats did not respond to electrical stimulation, but that, in some instances, it was functionally active before the eyes opened, i.e. before the ninth day. The centers for the fore limbs were found to respond earlier than those for the hind limbs, and head movements could be obtained only at a later date than movements of the limbs.

Weed and Langworthy (1926) and Langworthy ('27b), in newborn kittens, which, as in Mills' experiments, were stimulated under ether anesthesia, obtained fore limb movements, while movements of the hind limb could not be obtained until the kittens were 16 days old, while the facial area did not respond to electrical stimulation until the animals were 21 days of age (fig. 7A).

In dogs, Soltmann (1876) found the motor cortex unresponsive until the tenth day after birth, when fore limb movements were first obtained. On the thirteenth day movements of the hind limbs together with fore limb movements could be elicited. But it was not until the sixteenth day that movements were obtained from the facial area. Soltmann narcotized his puppies with ether, chloroform, or morphia.

Later, Ferrier (1880/86) agreed that in dogs no movements could be obtained until after the opening of the eyes, usually about the eighth day; he stated that the cortical centers in the dog generally do not react till about the tenth day, and that the centers for the fore limbs become excitable before those for the hind limbs.

Paneth (1885), however, using no anes-

thesia, obtained positive results in dogs of 24 to 48 hours of age. These puppies responded to electrical stimuli with fore limb movements prevailing, while hind limb movements were sparingly obtained.

Mills (1896) came to the conclusion that there is no proper functional cortical development in dogs before the eyes open, which seldom occurs before the tenth to the thirteenth day. He confirmed Soltmann's results in that he found movements of the head as a whole and of its various parts to be developed later than those of the limbs. In disagreement with Soltmann and with Ferrier, however, he found that in most, though not in all of his specimens, the hind limb area became functionally active at a somewhat earlier date than that of the fore limb, an observation which was not confirmed by subsequent investigators. In the cases of large dogs, such as the St. Bernard, the cortical motor centers became functionally active at a later date than in small breeds, like the terriers, or in mongrels, an important finding that seems to be in harmony with the more rapid physical and psychic development of the latter. Agreeing with Soltmann, Mills emphasized the fact that localization was at first somewhat indefinite, but gradually, though rapidly, became better defined. He found the principal centers active within the first thirty days of life, most of them before this limit. As did his forerunners, he stimulated his dogs while they were anesthetized with ether.

Michailow (1910) and v. Bechterew (1911) likewise obtained positive results in dogs during the first few days of post-natal life. They were then able to locate electrically excitable areas for both fore and hind limbs, for mastication and for neck movements. The facial area became responsive considerably later, not until 5 days after birth. The responses obtained from the facial area were closure of the eyes and ear movements. Several days

later they procured, in addition, movements of the upper lip. Von Bechterew, and before him Soltmann, emphasized the fact that there is a considerable individual variability and also variability according to the different breeds of dogs.

Cat and dog, as seen from the experiments of various authors, exhibit the striking phenomenon that the limb areas considerably precede the facial area in their response to electrical stimulation, and that, moreover, the fore limb area precedes the hind limb area. It seems logical to seek the explanation for this latter fact in a developmental adjustment to the functioning of the limbs. For in the placentals, just as in the marsupials, the fore limb plays a greater, guiding rôle from the time that the young of those animals born in immature state first make attempts to walk. But also in the young of those placentals which are well developed at birth, the fore limbs take the leading rôle in progression, just as in the adults of all quadrupedal mammals. This is probably the causal factor for the early cortical motor representation of the fore limbs. In agreement with this are the observations that among the marsupials and primitive placentals the hind limb area in some forms is either absent or only imperfectly represented in the motor cortex of the adult animal. In any case, the hind limbs are far less well represented than the fore limbs, which in all mammals readily respond to electrical stimulation of the cortex. Thus, as regards cortical motor representation, the fore limbs, probably in functional adaptation, precede the hind limbs not only in ontogeny but likewise in phylogeny (see later). It is not astonishing, therefore, that in the dog, as compared with the cat, response from the hind limb and facial areas more quickly follow the response from the fore limb area, from which movements may be obtained at birth in both animals. As is generally known, kittens

are born in a more immature state than are puppies, and the latter make quicker progress in general development during postnatal life. Yet the great delay in the response from the hind limb and facial areas in the cat (Weed and Langworthy, 1926) is rather astonishing. Renewed investigations with modification of the technique (e.g. stimulation of the animals without anesthesia) may yet lessen the apparently great difference between cat and dog.

The results of stimulation experiments on newborn and very young rabbits and guinea-pigs are interesting in comparison with the results which various investigators have obtained in opossum, cat and dog.

In the rabbit Tarchanoff (1878) did not obtain any movements until the animals were about 11 days old. Then it was possible to elicit fore limb and masticatory movements. Only considerably later were movements of the hind limbs obtained. Judging from Tarchanoff's protocols and from his concluding statements, the area for masticatory movements in the young rabbit was more responsive than was the fore limb area, while on the other hand the hind limb area did not give regular response (see later Mills, 1896, on hind limb movements in the rabbit).

In the guinea-pig, however, Tarchanoff found the motor cortex responsive even shortly before birth. This great difference in first appearance of motor response in the guinea-pig compared with the rabbit is undoubtedly correlated with the difference in the state of general development in which these two rodent types are born. While newborn rabbits are even less mature and more helpless than newborn kittens, guinea-pigs are born in a relatively mature condition with a well developed coat of fur and with open eyes, and ready to run around. Von Lenhossék (1889) also emphasized the fact that in the newborn guinea-pig the tracts of the spinal cord,

including the corticospinal system, are further advanced in their development and larger in size than in the newborn rabbit or mouse.

In the newborn guinea-pigs Tarchanoff obtained movements of mastication, as well as fore and hind limb movements. Langlois (1889) confirmed these findings. By far the easiest movements to obtain were the masticatory ones, for which Langlois easily located the center. Though he also obtained fore limb movements and, with stronger current, additional movements of the hind limbs, he was unable clearly to localize the limb areas.

Neither Tarchanoff nor Langlois mentioned whether in the masticatory movements of the young rabbits and guinea-pigs facial muscles of the orbicularis oris-buccinator group were involved. The inclusion of movements of this group in mastication is typical for the adult animals, especially in the case of the rabbit. From the fact, however, that Tarchanoff did not specifically state that movements of facial muscles occurred in any of his young rabbits, including those of 45 days of age, it may be assumed that movements of the orbicularis oris-buccinator group really were included in the masticatory movements. If this assumption is correct we have here a case where the fore limb area does not precede the facial area in its development.

It is very likely that in the various types of placentals developmental adjustments of the several motor centers take place according to the differences in behavior during early postnatal life.

III. RESULTS AND CONCLUSIONS FROM ANATOMICAL AND PHYSIOLOGICAL INVESTIGATIONS OF THE MOTOR CORTEX IN VARIOUS ORDERS OF MAMMALS

A. MONOTREMES

Martin (1898/99) explored with great care the entire cortex in two examples of

Ornithorhynchus and obtained practically the same results in each specimen (fig. 1). Movements from the facial field were procured most easily. Stimulation of most parts of the anterior half of the cortex resulted in a "screwing-up" of the contralateral eyelids, but this movement was aroused with the weakest current at a smaller area further back. This "screwing up" of the eyelid is, no doubt, caused through contraction of muscle portions corresponding to the m. orbicularis oculi. This muscle in *Ornithorhynchus*, as well as in *Echidna*, does not form a uniform complete sphincter around the eye, as it does in the marsupials and placentals, but is represented by several muscle portions (see Ruge, 1895; Schulman, 1905) which through synergic action may bring about the same effect as would a uniform m. orbicularis oculi.

From the large, ill-defined responsive motor area on the anterior half of the cortex Martin also obtained contraction of the anterior portion of the opposite "panniculus carnosus," causing the head to be rotated to the opposite side and drawing forward the shoulder. This action was evidently the result of the contraction of that part of the facialis musculature which has been erroneously included in the panniculus carnosus (compare Huber, 1931b). Responsible for the movement referred to by Martin is a powerful muscle of the superficial facial musculature (m. platysma), which expands from the shoulder region over the lateral side of the face to be secondarily attached to the duck bill shaped snout (see Huber, 1931b). Owing to its attachment this muscle may rotate the head and in addition may exert a pull upon the shoulder, just as Martin observed in his stimulation experiments. From these observations it becomes evident that the facialis field is well represented in the motor area of the cerebral cortex of *Ornithorhynchus*.

In addition, upon stronger stimulation, Martin obtained from the same large, ill-defined area on the anterior half of the cortex, definite advancement of the shoulder with flexion of the elbow and extension of the wrist followed by abduction of the shoulder, extension of the elbow and flexion of the wrist. The movement was, as Martin ascertains, precisely that exhibited by the fore limb of the animal when digging a burrow.

Martin's experiments reveal the important fact that in *Ornithorhynchus* facial and fore limb areas partly coincide. It is important, moreover, that Martin, even with the strongest current, failed to obtain the slightest movement of the hind limbs or tail from any part of the cortex.

B. MARSUPIALS

In the marsupials, especially in the opossum (*Didelphys*), the motor facial area has been reported by most authors as partly coinciding with areas from which movements of the fore limbs were also obtained (fig. 2). The fore limbs, on the other hand, appear still to have partial representation in the corpus striatum (Rogers, 1924).

As to the localization of the hind limbs in the opossum, the various authors do not agree in their findings. Some of them claim to have been able to localize a hind limb area in the motor cortex. Thus Herrick and Tight (1890), investigating the opossum, reported hind limb movements from an ill-defined area lying posterior to the orbital sulcus. Ziehen (1897) also reported that he obtained hind limb movements in the opossum, in addition to movements from fore limb and facial areas, which in part overlapped. The center for the facialis musculature required less current than that for the fore limb, which in turn responded to less current than the center for the hind limb, from which movements were obtained only with a very strong current.

Flashman (1906) reported hind limb movements in *Dasyurus*, which were, however, inconstant and diffuse.

C. and O. Vogt (1906/07) observed hind limbs movements in stimulating various representatives of the di- and polyprotodont marsupials. They emphasized, however, that these movements were very difficult to obtain, and were diffuse and inconstant—in fact, in several kangaroos no hind limb area could be detected—while the fore limb area in the di- and polyprotodont marsupials investigated always responded to the stimuli. The hind limb movements, when obtained, were usually movements of the whole leg, though occasionally only the musculature of the foot was involved. In contrast to this, discrimination of finer movements in the fore limb, as in the facial region, was quite marked.

Cunningham's (1897/98) reference to hind limb movements in one of his experimental animals (opossum) is not to be counted among the positive results. As Cunningham himself states, the animal was coming out of ether when these movements occurred. This made him conclude that they were of the spontaneous kind.

According to the observations of all these investigators, the hind limb area thus strikingly contrasts with the fore limb and the facial areas in its response to electrical stimulation. One may suspect that some of the investigators obtained hind limb movements through application of unduly strong current. It is most significant that several later investigators (Rogers, 1923, '24; Gray and Turner, '24; Turner, '24; Weed and Langworthy, '25; Langworthy, '27a) were unable to obtain movements of the hind limbs, trunk or tail in the opossum, despite careful exploration of the whole cerebral cortex.

This seems to be in agreement with the observation of Turner (1924) that in the opossum which he investigated the cortico-

spinal tracts did not extend caudalward beyond the cervical region. Turner, however, admitted that these tracts might possibly continue downward for some distance as unmyelinated fibers which do not constitute a compact tract, but are too scattered to be defined by the Cajal and Ranson silver stains.

Nevertheless, we can not completely disregard all the data of the former group of investigators of marsupials in view of the fact that among these authors who claimed positive, though inconstant results, were C. and O. Vogt, who had much experience in cortical stimulation. It is tempting to assume that in the evolution of their motor cortex the marsupials have not reached the stage where the motor centers for the hind limbs have definitely shifted into the cortex, and that their occasional, though ill-defined response depends on progressive individual variations of the experimental animal, besides other specially favorable conditions. Such a hypothesis would reconcile the conflicting results obtained by the various workers. In such instances where response of the hind limbs is obtained, subsequent investigation of the pyramidal system should be undertaken in order to ascertain whether the corticospinal tracts really extend caudalward as far as the lumbar or lumbosacral level of the spinal cord.

Within the facial area of the opossum, movements of the ear musculature, of the m. orbicularis oculi, and of the vibrissae can be elicited. The muscle group that moves the facial vibrissae is well represented in accordance with the important functional rôle that this tactile mechanism plays in the life of the animal.

C. PLACENTALS

While we have fair, though by no means fully correlated and exhaustive knowledge of the motor cortex of the more common

laboratory placental mammals (rat, rabbit, cat, dog, monkey (*Macacus* and *Cercopithecus*)) and of some of the rarer experimental forms such as the orang-utan, chimpanzee and gorilla, our knowledge of other placentals is still very fragmentary. There are a series of orders and suborders which have not been subjected to experimentation, while of the others only one or a few representatives have been studied.

1. Insectivores

Of this order only the hedgehog (*Erinaceus europaeus*) has been investigated (Mann, 1896; Ziehen, '97, '99; Probst, 1901; Weber, '06; C. and O. Vogt, '06/07) (fig. 3). The results obtained by these authors differ widely. They are in part uncertain and incomplete. For example, Mann failed to obtain response from any part of the facial musculature, while Ziehen (1897) and C. and O. Vogt (1906/07) observed movements of neither the m. orbicularis oculi nor of the ear musculature. Evidently those facial muscles which during the life of the insectivores play the greatest rôle, (i.e. the muscles of the snout) are the best represented (Ziehen, Probst, C. and O. Vogt), while the other muscles of the facialis group do not readily respond (see Ziehen '99, p. 169, in contrast to '97). The snout musculature appears to be in part bilaterally represented (C. and O. Vogt).

In addition to the facial area, centers for the fore and also for the hind limbs have been located by Mann, Ziehen and C. and O. Vogt. The responses obtained involved isolated, uncorrelated movements of only certain muscle groups. According to Ziehen, the hind limb area requires stronger stimuli than does the fore limb area. The Vogts emphasized the fact that the motor areas of the hedgehog in general are decidedly less responsive than are those of higher placentals. This may be the ex-

planation for the meagre or fully negative results of Probst and Weber.

The experimental findings of the various investigators seem to be in accord with the fact that in the hedgehog the cyto-architecture of the motor cortex is as yet but little evolved (Brodman, 1909).

2. Bats

One representative of the Microchiroptera, evidently *Vespertilio murinus*, the common small bat of central Europe, has been subjected to experimentation by Ziehen (1899) and by Merzbacher (1903). The results are not worth mentioning.

C. and O. Vogt (1906/07) stimulated eight specimens of *Pteropus Edwardsi* (fruit bat), a representative of the Macrochiroptera. They found the "head segment" with the facial area to be far more extensive and more responsive than the leg areas (fig. 4). Various subdivisions of the facial area were mapped out. These responded with three different kinds of "rhythmic movements" of the muscles of the snout, m. orbicularis oculi and ear musculature. From the leg areas the authors obtained what they considered satisfactory results only in their last specimen. These findings differed widely from those obtained from the other seven specimens. Both fore and hind limbs were represented, with partial overlap of the areas. These experiments have not been repeated.

3. Rodents

A series of authors have investigated, both morphologically and experimentally, the motor cortex of mouse, rat, rabbit, guinea-pig and ground hog (*Arctomys monax*).

C. J. Herrick (1926, p. 164) sums up with the following statement the work of Döllken, 1907; Brodman, '09; Isenschmid, '11; DeVries, '11; Winkler and Potter, '11; and Fortuyn, '14; who have independently

charted the cortical areas of rabbit, mouse and rat: "When the reports of their examination of the same species are compared the result is disquieting. All agree that in these lowly forms the boundaries between the various areas are indefinite and that the structural features by which the areas are distinguished are far less well defined than in higher brains."

In accord with this are the results obtained from cortex stimulation and ablation experiments by Ferrier, 1873, '74, '80/86; Fürstner, '76; v. Bechterew, 1886/87, '87, '11; Exner and Paneth, '87; Herrick and Tight, '90; Mann, '96; Mills, '95, '96; Ziehen, '97; Lashley, 1921; and W. K. Smith (unpublished). Upon considering this literature we realize that the data so far obtained are very incomplete, in part contradictory, and little correlated.

The excitable cortical centres of the rodents appear to be ill defined and variable. Several workers were unable to obtain hind limb movements, while others claimed a responsive hind limb area in addition to the areas for the fore limb, facial and masticatory musculature, etc. In these studies are included uncritical references to simultaneous movements of both hind limbs (Mann).

Mills (1896), after examination of a large series of different breeds of young and adult rabbits, emphatically denied the existence of a responsive hind limb area in this animal. He thus found the rabbit to be in striking contrast to the guinea-pig, rat and mouse. In these latter rodents he was able to confirm the general motor localization as previously found by Ferrier, who located a hind limb area in addition to the other areas. It is most significant that in the rabbit (compare v. Lenhossék, 1889; Simpson, 1914, '15), as in a series of other rodents (compare v. Lenhossék, 1889; Goldstein, 1903/04; Wallenberg, '03/04; v. d. Vloet, '06; King, '10;

Simpson, '12/13, '14, '15; Ranson, '13, '14; Linowiecki, '14; Reveley, '15), the corticospinal tract can be traced, although greatly reduced, at least as far as the lumbar portion of the spinal cord. In some cases this tract extended even to the sacral region. Thus in these rodents, including the rabbit, there evidently exists a definite anatomical basis for positive cortical motor response of the hind limbs. Swank (1932), however, consequent to extensive cortical destruction, could not trace the corticospinal tract of the rabbit below the upper level of the first cervical segment.

A decided advance was made through the fundamental studies of Lashley (1921), who combined cortex stimulation and ablation experiments with studies on behavior (fig. 5). He found that destruction of the electrically excitable cortex in the rat produced no discernible motor disturbances, but that simultaneous destruction of the motor area and the corpus striatum resulted in paralysis which resembled the effect of destruction of the excitable cortical area in more highly organized brains. Using these results as a basis, Lashley concluded that in these lowly placentals the motor cortex has a regulating function rather than real control over the voluntary movements. This seems to be in agreement with what Rogers (1924) found in a marsupial, the opossum.

From the available data on insectivores, bats and rodents, it becomes clear that in regard to the differentiation of the motor cortex these lowly organized placentals have evolved but slightly above the marsupials, and that in the primitive mammals (marsupials and primitive placentals), as Herrick (1926, p. 165) states, "the cortical differentiation is still in its incipency."

4. *Ungulates*

A few investigators (Maccacci, 1877; Ziehen, '99; Dexler and Margulies, 1906;

Simpson and King, '11; Bianchi, '20; Bagley, '22) have studied the motor cortex in this group, using the sheep as their experimental animal (fig. 6). The results are in part contradictory and indefinite. A series of responsive areas which show considerable individual differences have been mapped out. Among these is a facial area, which gives response of the contralateral and in part bilateral facialis musculature. Besides the main facial area Bagley located an additional well defined area which readily responded with ipsilateral contractions of facial muscles of the mouth. In agreement with Marcacci and in contrast to Simpson and King, Bagley found the facial area more responsive than the other areas. According to most authors (Marcacci, Ziehen, Bianchi, Simpson and King) movements of the fore legs are contralateral, and response from them is more easily obtained than from the hind legs. Marcacci was unable to obtain movements from the latter. In connection with this, it is important to note that Bagley was unable to trace the corticospinal tract beyond the cervical region.

The several authors emphasize the great difficulty of experimentation in the sheep. Dexler and Margulies stated that the results which they obtained were inconstant and uncertain. Simpson and King mentioned that in many individuals, motor responses were not obtained from one or more of the areas. And Bagley agreed with them, stating that only through frequent attempts were results obtained. Nothing could better illustrate how indefinite these results are than Bagley's statement (1922, p. 22) that upon stimulation in the leg areas he often obtained response from 2, 3 or even all 4 legs. These results must be carefully weighed in view of the fact that Bagley used only local anesthesia. Likewise Simpson and King, in part stimulating animals in the conscious state, obtained, at

times, movements of the opposite fore and hind legs together with movements of the hind leg of the same side. Moreover, they obtained from the left cortex of a 6 week old lamb, sucking movements combined with "wriggling" movements of the tail, upon stimulation of an area which corresponds to the facial area of the adult sheep. Under ether anesthesia this "sucking center" could not be found on the right side, nor was this area excitable on either side in a second lamb which was subjected to stimulation.

It should be added that destruction of the motor cortex in the sheep caused no obvious paralysis (Simpson and King).

In spite of the partly indefinite results and questionable data of these studies on the sheep, we may conclude that the motor cortex in this ungulate has evolved scarcely further than it has in the above discussed lower placentals.

5. *Carnivores*

A series of authors (Fritsch and Hitzig, 1870; Ferrier, '73, '74, '80/86; Hitzig, '73, '74, '04; Luciani and Tamburini, '78; Rosenbach (and v. Bechterew), '83; Paneth, '85; v. Bechterew, '86/87, '87, 1911; Exner and Paneth, '87; Herrick and Tight, '90; Mann, '96; Mills, '94, '95, '96; Weber, 1906a; Weed and Langworthy, '26; Langworthy, '27b; Smith, '32; and others) have investigated the motor cortex in carnivores, especially in cat and dog. From these investigations and from our own on the cat and dog (Huber and Smith, unpublished), it becomes evident that the motor cortex in these carnivores has evolved further than in representatives of the above discussed orders of placentals.

The electrically excitable areas are situated adjacent to the cruciate sulcus (see fig. 7B). Referring in this discussion only to the areas for the limbs and face, we may note that the motor cortex responds

with more elaborate movements of the entire musculature of the fore and hind limbs (see Smith, 1932, in regard to the greater development of the fore limb area compared to the hind limb area in the American black bear).

The readily responsive facial area appears to be clearly separated from that of the fore limb. Contraction of the facialis musculature is prevailingly contralateral, but to a certain extent also bilateral. Within the facial area those muscles that move the long mystacial tactile vibrissae (m. naso-labialis and m. maxillo-naso-labialis) are the most responsive ones, especially in the cat. Portions of the m. orbicularis oculi contract synergically with the m. naso-labialis. The two muscles constitute a morphological and functional unit, and the cortical center for this genetic muscle group evidently has not undergone a further clear subdivision.

From the well defined leg areas purposeful movements of the contralateral limbs are regularly and easily obtained, this being in contrast to the placentals already discussed. There is a small transitional zone between the fore limb and hind limb areas from which movements of the hind limbs are initiated simultaneously with the last slight movements of the fore limb. The movements of the limbs are those which occur in the characteristic progression of the animal. This can be most clearly demonstrated in the case of the dog (Huber and Smith).

None of the more primitive carnivore types have so far been investigated satisfactorily (compare e. g. Weber, 1906a).

6. Primates

Within the primates a far greater variety of forms has been studied than in any other order of the placentals. It is indeed of great importance that these investigations should cover the main groups of the pri-

mates so that, on the one hand, the findings on the lower representatives of this order might be linked with those on primitive types of other placental orders, and, on the other hand, through comparative study of the catarrhine monkeys and of the anthropoid apes, a key to the understanding of the complex conditions found in the human motor cortex might be obtained.

It should be added that *the author has purposely confined himself to the discussion of the true "motor" cortex*. He has refrained from reference to the excitable ocular areas on the frontal and occipital poles of the fore brain, which give responses of an entirely different character, not to be confused with the typical response of the main motor area, a fact which for the first time was clearly pointed out by Grünbaum and Sherrington (1901/02).

A. Prosimiae (*Tarsioidea* and *Lemuroidea*)

Tarsius has not yet been subjected to cortical stimulation, but there are records of observations on a number of the Lemuroidea.

Völsch, in collaboration with Ziehen, published (1906) a short account of the stimulation of one lemur, probably *Lemur mongoz*. The data obtained were rather incomplete.

This study is preceded by a short reference to the stimulation and histological investigation of the brain of *Perodicticus* by O. Vogt (1906), in connection with a preliminary communication of extensive studies by C. and O. Vogt on the motor cortex.

Soon afterwards appeared the fundamental work of C. and O. Vogt (1906/07), containing the results of stimulation experiments on eight Lemuroidea of various genera and species: 3 *Lemur macaco*, 2 *L. mongoz*, 1 *Perodicticus potto*, 1 *Chirogale crossleyi* and 1 *Otolemur* (= *Galago*) *crassicaudatus*. This study was correlated with histological investigations by Brodmann (compare C.

and O. Vogt, 1906/07, p. 407; Brodmann, 1906).

Then followed the publication by Mott and Halliburton (1908) of stimulation and ablation experiments on one lemur, correlated with histological studies.

From the studies of these various authors it may be concluded that the motor cortex of the brain of the Lemuroidea has not attained a high degree of differentiation. Location, extension and subdivisions of the motor cortex were found similar to those in the lower platyrrhine monkeys.

In *Perodicticus* (fig. 9) the responsive motor area showed a relation to the sulcus "ce" similar to the relation of the motor area to the sulcus centralis in the simian brain. This was corroborated through histological studies (O. Vogt, 1906; Brodmann, 1906). The Vogts therefore declared these sulci homologous. Brodmann, moreover, gave evidence that the sulcus "e" of the brain of *Lemur*, *Nycticebus* and *Propithecus* is not identical with the sulcus centralis. He demonstrated that sulcus "e" lies amid the area precentralis, which is characterized by large pyramidal cells, the motor cells of Betz (1874) (compare Brodmann, 1906, p. 377; 1909/25, p. 168/169, 175 and fig. 100). These data suggest great caution in attempts to homologize the cortical sulci of the various, diversified types of the lemuroid stock.

In the brain of the Lemuroidea distinct responsive areas for the head, trunk, tail and both extremities have been mapped out (see figs. 8 and 9). The sequence of parts represented, proceeding from the superior surface of the hemisphere downward, is: Tail, hind limb, trunk, fore limb, head. This arrangement is characteristic of all primates. From the facial area movements of the m. orbicularis oculi and the musculature of the ears and snout have been obtained. None of the investigators

referred to vibrissae movements, which in the lemur should be expected to be an outstanding phenomenon. Easily obtainable contralateral ear movements were reported (C. and O. Vogt, Mott and Halliburton). This is in agreement with the fact that in the lemurs the ear musculature is well developed and differentiated (Ruge, Huber), corresponding to the great rôle which it plays in the prevailing nocturnal life of the animals. The closure of the eyes was found to be prevaillingly contralateral, while the snout musculature gave both contralateral and bilateral responses (C. and O. Vogt). The Vogts emphasized the more caudal position of the area for closure of the eyes as being in striking contrast to the more oral position of the same area in the simian brain.

From various motor areas of the lemur brain responses were evidently difficult to obtain and not constant throughout, as can be seen from the protocols of the Vogts, and from the fact that Zichen and Völsch only with stronger current obtained a single movement of the extensor musculature of the thigh, while no movements could be obtained from the leg, feet or toes.

B. Simiae

I. Platyrrhine monkeys

The extensive investigations of C. and O. Vogt (1906/07) included experiments on 21 specimens, representatives of both families of the platyrrhines.

a) Family Hapalidae (= Callitrichidae) (marmosets)

The animals subjected to experimentation were 4 *Callithrix* (= *Hapale*) *penicillatus*, 2 *C. jacchus* and 1 *Midas ursulus* (= *Myiastax midas*).

In agreement with the lowly position of the marmosets their little or unfurrowed (lissencephalic) brain has no sulcus cen-

tralis. The responsive motor cortex, however, shows a topographic relation similar to that found in the representatives of the Cebidae, the second family of the platyrrhines, which possess a well defined sulcus centralis (see fig. 10) or, in the case of *Nyctipithecus* (= *Aotus*), at least indications of a central furrow (compare C. and O. Vogt, p. 390, and figures on plate 7). This fact, which is in full agreement with the histological findings of Brodmann (1909/25), is very important. It proves that in the phylogeny of the primate brain the cyto-architecture precedes the formation of the sulci and gyri.

In the motor cortex of the marmosets responsive areas for the trunk, tail, upper and lower extremities and head, including the facial field, have been mapped out. Stimulation of the arm area gave prevalently generalized arm movements. Finger movements, when obtained, almost always involved all of the digits. The authors emphasized the extreme difficulty in obtaining any isolated finger movements. This seems to be a further instance of the lowly organization of the marmoset brain compared with those of the higher platyrrhines and the catarrhines.

In an additional study on a marmoset, Mott, Schuster and Halliburton (1910) reported the results of stimulation and extirpation experiments combined with histological studies. The authors emphasized the large extension of the head area, including the facial field, which could be further subdivided and gave a more ready response than the fore and hind leg areas. In contrast to their previous investigation on the lemur (Mott and Halliburton, 1908), no response from the ear musculature was obtained in the marmoset. Nor did the Vogts record ear movements. However, this negative result must not be considered final. It should rather be expected that a more

elaborate investigation of the facial area will yield ear movements, since the marmosets possess a well developed and fully functioning, though not highly differentiated ear musculature (Huber, 1931a).

b) Family Cebidae

C. and O. Vogt seem to be the only authors who have experimented on representatives of this family. They investigated 2 *Nyctipithecus* (= *Aotus*) *trivirgatus*, 1 *Pithecia satanas*, 1 *P. hirsuta* (= *P. monacha*), 5 specimens of *Cebus*, including various species, 1 *Alouatta nigra* (= *Alouatta caraya*), 1 *A. seniculus* and 3 *Ateles ater*.

Nyctipithecus (= *Aotus*) is of special interest, as this type, in regard to many structures, including the facialis musculature (Schreiber, 1928; Huber, 1931a), appears to combine characteristics of the lowly marmosets and the higher Cebidae. Of the two specimens examined by the Vogts, one, in correspondence with the marmosets, showed no indication of a gross morphological demarcation between the electrically responsive precentral and non-responsive postcentral regions, while in the other specimen these areas were separated by a furrow, evidently homologous to the well marked sulcus centralis of the higher Cebidae and all the catarrhines, including the Old World monkeys, apes and man. The topography and subdivisions of the responsive motor areas of *Nyctipithecus* were found to be largely the same as in the marmosets, with fewer absolute foci than in the higher Cebidae (pp. 386-387 and plate 7).

In all the higher Cebidae the topography of the motor cortex was found similar to that of the lower catarrhines (fig. 11). The responsive area never extended posterior to the sulcus centralis Rolandi. Some important differences were noticed in the various types. Those concerning the tail area are significant. It is not

astonishing that this area in the higher Cebidae has undergone a greater extension and fuller elaboration. The higher representatives of the Cebidae, in contrast to the marmosets, the lower Cebidae and all of the catarrhines, possess a prehensile tail which is a great aid in the arboreal activity of these monkeys. This tail is used much as a fifth hand. Through acquisition of high sensitivity on the hair free flexor surface, this prehensile tail has become a remarkable sensory organ, which shows the highest differentiation in the woolly monkey (*Lagothrix*) and in the spider monkey (*Ateles*) (see further Tilney, 1928, vol. I, p. 192). Thus it is not astonishing that the tail area in the spider monkey (*Ateles*) was found to be more extensive and better isolated than in *Alouatta*, *Cebus* and *Pithecia*. This area was found further subdivided, and it gave a more ready response than in the other Cebidae. In the spider monkey more elaborate movements of the hand and fingers were also obtained. These interesting data suggest indeed a close correlation of morphological and physiological features of the motor area with the habits of the spider monkey, the cleverest acrobat among the platyrrhines, an arboreal type similar to the gibbon among the catarrhines.

As to the facial area of the platyrrhine cortex, C. and O. Vogt's investigations bring only scanty contributions. It should be expected that here also a further elaboration would take place in the ascending scale of platyrrhines, paralleling the evolution of the facialis musculature. In the higher platyrrhines the fuller use of the more elaborate muscles of the face proper (mimetic muscles) is in striking contrast with the prevailing use of the musculature of the ear and snout and the specialized vibrissae-moving facial muscles in the lower platyrrhines and prosimians (see Huber, 1931a).

II. Catarrhines

a) Catarrhine Monkeys (*Cercopithecidae* sive *Lasiopygidae*)

Hitzig (1874, '04) was largely correct with the exploration and delimitation of the motor cortex of his only macaque (*Macacus* sive *Pithecus*). Great credit must be given to him, because he was the first clearly to demonstrate and emphasize the fact that the electrically responsive area does not extend behind the sulcus centralis Rolandi.

Following the publication of Hitzig, Ferrier (1874, '75, '80/86) claimed a much more extensive motor area for the macaque, including the postcentral gyrus, with additional areas scattered all over the outer surface of the cortex and even an area on the lower surface of the temporal lobe (gyrus uncinatus). This great deviation between the findings of Hitzig and Ferrier was obviously due to the application of too strong a current by the latter. Ferrier's detailed exploration of the motor area in a series of macaques brought further valuable data. Careful examination of the detailed protocols, however, reveals a series of very questionable and uncritical observations.

Ferrier's ablation experiments undertaken on several macaques were an important addition. With these experiments he demonstrated that destruction of the whole or part of the excitable motor area results in disturbances more serious than in the dog, cat and rabbit. These latter had been subjected to similar experiments by a series of investigators (Hitzig, Ferrier, Munk *et alii*). It had become known that in dog and cat the effects of destruction of the motor centers, though in the beginning well marked, largely disappeared within a few days. In the rabbit such disturbances were found even less severe than in the cat and dog, and also of much

shorter duration. Since Ferrier was unable to keep alive his operated macaques over a sufficiently long period, he was unable to observe whether the marked paralysis was temporary or permanent. Subsequent ablation experiments by other investigators (see e.g. Biedl, 1897) showed that in the macaque restitution of the impaired functions takes place (see also Fulton and Keller, 1932). The gravest and longest lasting paralyses appear to be those of the hand.

A series of investigators (Horsley and Schäfer, 1884, '89; Schäfer, '87; Beevor and Horsley, '87, '94; Munk, '90; Flood, '94; v. Bechterew, '98, '99; and others) subsequently investigated the motor cortex of lower catarrhines, especially of the Bengal macaque, *Macacus* (= *Pithecus*) *rhesus*, and the guenon, *Cercopithecus callithrix* (= *Lasiopyga callitrichus*). Partly influenced by Ferrier's inaccurate findings, these authors mapped out the motor area in an extension far greater than that which actually exists. They always included the postcentral gyrus in the electrically responsive motor area. Although later investigators have proven this to be incorrect, these studies nevertheless contributed greatly to the knowledge of the motor cortex of the lower catarrhines.

Grünbaum and Sherrington's convincing demonstration (1901/02) that in the anthropoid apes the excitable cortex is restricted to areas anterior to the sulcus centralis Rolandi should have led to a reconsideration of Hitzig's previous similar restriction of the motor cortex in the macaque. Yet further studies upheld Ferrier's view.

Munk (1903), in his investigations of the changes in motility following loss of sensibility in the upper extremity in fourteen Old World monkeys (*Macacus* (= *Pithecus*) *rhesus*, *M. cynomolgus* (= *Pithecus* *irus*), and *Cynocephalus* (= *Papio*)), men-

tioned the fact that he regularly obtained, with weak current, flexion of the thumb and in addition (if his statement on pp. 1072-1073 is rightly interpreted) closure of the hand and movements of the fore arm from various points of the postcentral gyrus, which he compared with corresponding sections of the precentral gyrus. He stressed the fact that he stimulated his monkeys in the conscious state, which enabled him to appreciate finer differences in motility response. Thus he found, in contrast with previous workers, that loss of sensibility in the extremities resulted in a notable decrease of the motility.

Rothmann (1904) claimed that in various representatives of macaques which he had studied the postcentral gyrus was directly excitable. Because of this he insisted that the postcentral gyrus is to be included in the motor field. The evidence most convincing to him lay in the fact that three weeks after ablation of the precentral area combined with partial section of the lateral cord, definite response was obtained from the corresponding postcentral segment upon stimulation. It should be noted that he used a very strong current. In a second paper (1907) Rothmann defended anew his viewpoint against the opposite conclusions of earlier workers (Hitzig, 1874, on the macaque; Grünbaum and Sherrington, 1901/02 and '04, on the anthropoid apes; and Brodmann, '04, on a series of lower catarrhines, namely macaques and guenons) who claimed that the postcentral gyrus was electrically inexcitable.

Weber (1906), after stimulating a macaque, again confirmed Ferrier's findings, including the extension of the excitable motor area into the postcentral gyrus.

Then followed the important contributions of various investigators, which finally led to a more correct delimitation of the motor areas in the lower catarrhines. The

findings of these authors confirmed Hitzig's (1874) restriction of the electrically excitable motor cortex to areas anterior to the sulcus centralis Rolandi.

Probst (1903) emphasized the fact that in stimulating a series of pig-tailed macaques, *Macacus* (= *Pithecus*) *nemestrinus*, and hamadryas baboons, *Cynocephalus* (= *Papio*) *hamadryas*, he always found the precentral convolution excitable in its entire extent. From the postcentral gyrus, on the other hand, motor responses, if obtained at all, were elicited from single points only. In several of Probst's animals the postcentral gyrus gave no response whatever. He therefore considered the motor function of the postcentral gyrus to be of subordinate importance, yet admitting that this area has a small share in the motor field of the cortex.

More radical, however, was Brodmann (1904), who opposed Rothmann in a vigorous discussion, referring to Grünbaum and Sherrington's investigations upon anthropoid apes and to the results of the then recent stimulations of the motor cortex of human patients by Krause (1904) which he personally had witnessed. Brodmann was in the position to present direct evidence from stimulation and ablation experiments, which he had undertaken jointly with C. and O. Vogt, that also in the lower catarrhines (macaque and guenon) the excitable motor area is confined to the precentral gyrus (see further Brodmann, 1905).

Jolly and Simpson (1907), inspired by Grünbaum and Sherrington's masterly experiments on anthropoid apes (1901/02, '04) and in doubt about Rothmann's findings, undertook a more careful investigation of the motor cortex in *Macacus* (= *Pithecus*) and *Cercopithecus callitrichus* (= *Lasiopyga callitrichus*). After inserting a thin plate of vulcanite into the sulcus centralis they stimulated the postcentral gyrus, and ob-

tained no response. By so modifying their technique they now limited the motor cortex to areas anterior to the sulcus centralis. The studies of following authors, including ourselves (Huber and Smith), bring evidence that such special care of isolation is not needed, and that careful technique and discriminative judgment lead to the same correct results.

About the time of Jolly and Simpson's publication, Sherrington, in his book on "The Integrative Action of the Nervous System" (1906), emphasized the fact that in *Cercopithecus callitrichus* (= *Lasiopyga callitrichus*) the excitable motor area does not extend posterior to the sulcus centralis (Sherrington, 1906, fig. 75, p. 297). The same was demonstrated in the study by Roaf and Sherrington (1906) on *Cercopithecus callitrichus* (= *Lasiopyga callitrichus*) and *Cynocephalus anubis* (= *Papio* sp?).

Also about this time the work of C. and O. Vogt (1906/07; see also preliminary report by O. Vogt, 1906) appeared. These authors experimented on a variety of animals of the subfamily Cercopithecinae (= Lasiopyginae): *Macacus* (= *Pithecus*) *rhesus*, *Inuus inuus* (probably the Barbary ape, *Simia sylvanus*), *Cynomolgus* (= *Pithecus*) *fascicularis*, *Cynomolgus* (= *Pithecus*) *sinicus*, *Cercocebus fuliginosus* (= *Cercocebus aethiops*), *Cercocebus collaris* (= *Cercocebus aethiops*), *Mona* (= *Lasiopyga*) *mona*, *Mona* (= *Lasiopyga*) *campbelli*, *Cercopithecus pygerythrus* (= *Lasiopyga pygerythra*). The data obtained from the experiments on these monkeys, 27 in number, were discussed in detail and charted in both individual and combined schematic figures (for latter, see C. and O. Vogt, plate 3, figs. 2a and b, 3). In addition, a single specimen of *Semnopithecus* (= *Pygathrix*) *entellus*, representing the Semnopithecinae (= Colobinae), the second sub-family of the Cercopithecidae, was stimulated. The results obtained from this animal (fig. 13) were practically

identical with those procured from the *Cercopithecinae*.

In the catarrhine monkeys, as in the platyrrhines, occasional reactions may be obtained from points of the postcentral area close to the sulcus centralis, if somewhat stronger current be applied than that necessary to elicit response from the corresponding sections of the precentral gyrus. This is a generally observed phenomenon and was probably responsible for the misconception that the excitable motor cortex extends into the postcentral gyrus. The excitability in the postcentral gyrus gradually fades out caudalward in the direction away from the sulcus centralis, and no genuine response from the postcentral gyrus can be obtained. The Vogts gave the explanation that the apparent response from the area posterior to the sulcus centralis must be due to irradiation of the current from there to the corresponding section anterior to the sulcus. This they found to be in accord with the fact that after ablation of the postcentral area there was no paralysis in the organs which became paralyzed through destruction of the corresponding segment of the precentral gyrus. Thus the Vogts definitely restricted the excitable motor area in all the lower catarrhines, just as in the platyrrhines, to the area anterior to the sulcus centralis (see figs. 12 and 13).

In regard to the responses from the precentral gyrus of the lower catarrhines the findings of the Vogts largely agree with those of both earlier and later authors, including ourselves (Huber and Smith) on the macaque. Response is readily and consistently obtained and the movements elicited are quite elaborate, though not as elaborate as those found in the anthropoid apes. Thus, for example, stimulation of the hand and finger area produces no such clearly isolated movements of the individual fingers as Sherrington and his co-

workers have obtained in the anthropoid apes. Likewise the movements obtained from other parts of the body are not as detailed as in the anthropoid apes (see later).

Lewandowsky and Simons (1909), being still in doubt about the inexcitability of the postcentral gyrus, and rather favoring Rothmann's findings, undertook investigations with a view to settling this question. Repeating the experiments of Brodmann (1905), they extirpated the precentral gyrus in a series of eight Old World monkeys (macaques and guenons), leaving the postcentral gyrus intact for subsequent stimulation. After the elapse of a long period (3 to 6 weeks), they found that following this destruction of the precentral region the postcentral gyrus was not responsive to stimulation by even an extremely strong current. Extirpation of the postcentral gyrus, on the other hand, did not influence the excitability of the precentral convolution, which, as before, remained responsive to weak currents.

Convincing as were these experiments, Rothmann (1912) nevertheless opposed Lewandowsky and Simons, producing data from additional investigations. Yet the results of temporary freezing of parts of the motor cortex, an ingenious method introduced by Trendelenberg (1910, '11) in an attempt to avoid possible accessory injuries with the ablation method, did not produce satisfactory confirmation, as Rothmann himself admitted. Nor are the results of Rothmann's additional and somewhat modified ablation experiments convincing.

Lewandowsky and Simons (1913) justly criticized Rothmann (1912), in that he failed to verify the extent of his ablations by histological study, which method alone would have given full proof as to whether or not he had succeeded in completely removing the precentral gyrus.

Fulton and Keller (1932) investigated the effects of ablation of the cortical leg area upon the plantar reflexes, especially the Babinski, in a series of catarrhine monkeys of various types. They found that removal of the leg area on one or both sides of the motor cortex failed to produce the Babinski reflex in the macaque (*Pithecus*), mangabey (*Cercocebus*), patas monkey (*Erythrocebus*), and guenon (*Lasiopyga*). Only when the lower lumbar segments were freed completely from higher control by hemisection of the spinal cord was the Babinski response noted in these monkeys. This indicated that the Babinski in these animals is not controlled by the cortico-spinal pathways. In the baboon (*Papio* and *Theropithecus*), on the other hand, removal of the cortical leg area led to the appearance of the Babinski reflex. The significant observation was made that the baboon was slower to recover motor power following a lesion in the leg area than were the other monkeys. Fulton and Keller therefore concluded that "cortical dominance" is more highly developed in the baboon than in the other Old World monkeys studied.

In addition to the above quoted stimulation and ablation experiments, detailed investigations on the cyto-architecture of the motor cortex of the brain of lower catarrhines (*Macacus*, *Cerocopithecus*) were undertaken by various authors (Mellus, 1904/05; Brodmann, 1906; Nanagas, 1922/23; and others). The results of these studies agree closely with those obtained from electrical stimulation.

Thus gradually, through the contributions of a number of investigators, a more accurate and fuller knowledge of the so-called "motor" cortex of the lower catarrhines has come about.

b) Hylobatidae (Hylobates and Symphalangus)

The work of C. and O. Vogt (1906/07) includes a short reference to a stimulation

experiment by Brodmann on the left hemisphere of a siamang (*Symphalangus syndactylus*) (fig. 15). It would be expected that the Hylobatidae would occupy a position intermediate between the lower catarrhines and the big anthropoid apes. This was found to be true. In contrast to the lower catarrhines the head area in this siamang appeared relatively small in comparison with the extremity areas. Among these the arm area exhibited a striking increase in size.

A fuller experimental and histological investigation of the motor cortex in the "black" gibbon (= *Hylobates* sp ?) was later undertaken by Mott, Schuster and Sherrington (1911) (fig. 14). The authors emphasized the remarkable forward expansion of the responsive motor cortex (fore limb area) in the region of the middle frontal convolution. This was explained as a correlation with the use of the arms in the brachiating habits of the gibbon.

Fulton and Keller (1932) obtained essentially similar results from cortical stimulation of a specimen of *Hylobates agilis*. They also extirpated the leg area in this specimen (as well as in an example of *Hylobates leucogenys*). This led to the appearance of a strong positive Babinski reflex; and the return of voluntary power was much slower than in either the baboon or the other catarrhine monkeys that they studied. These results indicated the greater development of "cortical dominance" in the gibbon.

c) Pongidae or Great Anthropoid Apes (Orangutan, Chimpanzee and Gorilla)

It was not until 1891 that for the first time the motor cortex of a representative of the great anthropoid apes, an orang, was subjected to experimentation by Beevor and Horsley. This was a further step in the study of the primate cortex and toward the knowledge of the motor functions of

the human brain. A comparison of this publication with Beevor and Horsley's previous study on the macaque (1887) reveals a far more exact delimitation of the responsive motor area, which however, was still shown as extending partly into the postcentral gyrus. A series of details, including the observation of bilateral movements of the lip musculature, movements which have not been mentioned in the subsequent publications of Sherrington and his co-workers, need corroboration through further experiments.

The experiments of Beevor and Horsley on the orang constituted our only knowledge of the motor cortex of the great anthropoid apes until Grünbaum and Sherrington published two short preliminary accounts of their famous experiments on seven specimens, i.e. on the orang-utan (1901/02), the chimpanzee (1901/02, '04) and the gorilla (1901/02, '04).

A later publication by Roaf and Sherrington (1906) described experiments on another orang. An additional, short account of the stimulation experiment of an orang is included in C. and O. Vogt's work (1906/07).

It would be expected that the differentiation of the motor cortex in primates would parallel the general evolution of the brain. This was confirmed through the experiments. There is a decided advance in the anthropoid apes when compared with the gibbons and the catarrhine monkeys.

Grünbaum and Sherrington (1901/02, '04) found that the electrically responsive cortical motor area in the anthropoid apes unbrokenly occupies (this in contrast to Beevor and Horsley) the whole length of the precentral convolution, and in most places the greater part or the whole of its width (see also Sherrington, 1906, p. 272) (figs. 16-18). In contrast to the lower catarrhines it extends downward almost as far as the fissura lateralis Sylvii. At the

upper mesial edge of the hemisphere the motor area extends over upon the mesial surface of the hemisphere and posteriorly into the depth of the sulcus centralis. This is the posterior limit of the responsive motor area. It was also demonstrated that the postcentral gyrus is electrically non-responsive (Grünbaum and Sherrington, C. and O. Vogt). This was confirmed through ablation experiments (Grünbaum and Sherrington, 1901/02). There were no obvious symptoms of paresis upon ablation of large parts of the postcentral gyrus. Moreover, subsequent histological investigations by Campbell (1905) on the orang and chimpanzee showed that the large pyramidal cells did not extend posterior to the sulcus centralis Rolandi. It was likewise demonstrated by Holmes and May (1909) that chromatolysis consequent to cutting of the corticospinal tract in the upper cervical region of the chimpanzee did not extend behind the sulcus centralis. Thus through stimulation and ablation experiments and through correlated histological studies it was definitely proven that the motor area in the anthropoid brain, as in the lower catarrhines and the platyrrhines, is restricted to areas anterior to the sulcus centralis Rolandi.

In addition to the surface of the motor area that is actually exposed, there is a very considerable excitable area hidden in the deep, individually variable sulci which are so characteristic of the anthropoid brain. Grünbaum and Sherrington judged this hidden area to be as large as the free surface of the motor area (Sherrington, 1906, p. 278). Later, however, Leyton and Sherrington (1917) expressed the opinion that the hidden area probably amounts to about one-third of the entire motor cortex. Sherrington (1906) indorsed Beevor and Horsley's view that the motor cortex of the anthropoid brain forms a relatively smaller fraction of the total surface of the

neopallium than it does in the lower catarrhines. But he emphasized the fact that the motor area has grown in absolute extent, and that its relative decrease is caused by the still greater increase of other areas belonging to the so-called "silent" fields. This vast expansion of inexcitable, richly convoluted fields is indeed one of the most outstanding features of the highly organized neopallium of the anthropoid brain. In this, the great anthropoid apes closely resemble man.

Within the excitable motor area of the anthropoid ape brain the regions representing the various parts of the body were found to be in an arrangement which largely corresponds to conditions in lower catarrhines and higher platyrrhines (Beever and Horsley, Grünbaum and Sherrington, C. and O. Vogt, and subsequent authors). All investigators agree, however, that there is a greater integration of localized movements in the anthropoid ape as compared with the monkeys (Sherrington, 1906). More elaborate and very numerous movements from small subdivisions of the motor area can be obtained from the anthropoid brain. Thus, for example, from the arm area isolated movements of the individual fingers were obtained upon stimulation of certain points. Other small parts of the body were represented in a similar way. Hines (1929), in a critical review, states that "combination of discrete movements into a coördinated whole is more evident in the anthropoid cortex than in that of monkeys or of such laboratory animals as the rabbit, dog or cat."

In regard to the cortical representation of the mimetic musculature of man, comparative anatomical investigations on the catarrhine monkeys and the anthropoid apes are of great significance. In catarrhine monkeys, and also in anthropoid apes, the mimetic musculature not only of the upper but also of the lower part of the face, es-

pecially of the lips, has been reported to be in part bilaterally represented in the motor cortex (compare e.g. Beever and Horsley, 1894, on the macaque; 1891, on the orang). Such bilateral movements of the lip musculature in the orang have not been confirmed by subsequent investigators. Contrary to Beever and Horsley, Sherrington and his co-workers found that bilateral representation of the mimetic musculature in the anthropoid apes is restricted to and even accentuated in the muscles of the upper region of the face (i.e. the m. orbicularis oculi, mm. depressor and corrugator supercilii and m. frontalis), but most noticeable in the m. orbicularis oculi (Grünbaum and Sherrington, 1904; Leyton and Sherrington, 1917). In this respect the big anthropoid apes seem closely to resemble man, in whom, as seen from clinical cases and physiological observations, the mimetic muscles of the upper part of the face are evidently bilaterally represented. It is a well known fact that in man, in the facial palsy resulting from central lesions restricted to one hemisphere, the mimetic muscles of the upper part of the face are but little impaired, whereas there is a complete facial palsy in the lower part of the face. Thus, comparative investigations of the anthropoid apes and man bring clear evidence against the view of some authorities (see Krause, 1911, Bd. I, p. 157) that the bilateral innervation of these muscles is a subcortical one.

In exploring the motor cortex, Sherrington and his co-workers found it necessary to prick or tear small holes in the arachnoid to let out the cerebrospinal fluid, in order to avoid spread of current into areas adjacent to those under stimulation. Because of the characteristic rich pattern of convolutions, which are separated by deep sulci, and because of the closeness of the numerous small subdivisions of the motor field, stimulation experiments on the an-

thropoid brain require more precaution than do experiments on monkey brains. It is obvious that in the exploration of such a highly organized motor cortex only the unipolar method of stimulation could give satisfactory results.

Most interesting are the results of ablation experiments undertaken by Sherrington and his co-workers. Even the first communication by Grünbaum and Sherrington (1901/02) includes a short account of such experiments. Additional data, including references to the facial field, are given in their second communication (1904). Further statements are contained in Sherrington's book (1906), in the short publication of Graham Brown and Sherrington (1913a), and in Leyton and Sherrington's full presentation of the subject (1917). According to these accounts, extirpation of the arm area caused an immediate, severe crossed brachioptegia, which affected the fingers most. The paresis diminished rapidly, and in six weeks' time the animal had in large measure recovered the usefulness of the limb. Subsequent extirpation of the arm area of the second hemisphere produced no noticeable change in the paretic and partly recovered arm, but, as would be expected, resulted in a paresis of the opposite arm. A lesion of the leg area similarly caused temporary paresis of the opposite leg, especially in the toes and at the ankle joint. This lesion was smaller and the recovery more rapid than in the instance of the arm area lesion. Ablation of the facial area resulted in crossed hemiparesis in the lips, cheek, nasal fold, lower eyelid (very slightly), but not in the upper lid, eyebrow and frontal region. Recovery from these lesions occurred. Records of these experiments have been presented as moving pictures (Graham Brown and Sherrington, 1913b).

Sherrington and his co-workers offered no explanation as to what mechanism is

involved in the restoration of the motor function after excision of the electrically excitable motor area. The fact that after ablation of the corresponding motor area of the other hemisphere no change in the partly recovered limb took place, definitely proves that the second hemisphere did not play a rôle in the recovery of the originally affected limb (i.e. the limb contralateral to the cerebral lesion). On the other hand, the regained voluntary motility of the extremities, especially of the upper limb, and notably of the hand and fingers, is of such a complex nature that it somehow suggests cortical control as normally exists before the operation. It seems possible that the ablated portions representing the electrically excitable motor areas do not really cover the potential motor field, which may be much more extensive than it would appear from stimulation experiments. Thus Rothmann (1905) claimed that the actual motor area is far greater than that which is electrically excitable; in particular, he judged the upper extremity area to be of enormous extent. Sherrington did not seem to consider it likely that the remaining, perhaps less specialized, adjacent potential motor areas of the cortex take over the function after excision of the electrically excitable zones. In the experiments of Sherrington and his co-workers (e. g. in the case of ablation of the hand area) neither the ablation nor excitation methods gave evidence that the remaining part of the arm area had taken over the function of the extirpated hand region. Nor was the postcentral gyrus especially altered under experimentation; it had not become an area stimuable for arm, hand, or other movements, nor did subsequent ablation of the adjoining postcentral region cause recrudescence of the arm paresis. The authors likewise demonstrated that recovery of function was not the result of regeneration of the areas de-

stroyed (compare Leyton and Sherrington, 1917, pp. 207 ff.). Thus this fundamental question remains unsettled and suggests renewed investigation.

In connection with ablation experiments, Fulton and Keller (1932) mapped out the electrically responsive cortex in chimpanzees. After ablation of the leg area, the Babinski reflex appeared in two phases. Paresis was more profound and more lasting than in the monkeys or the gibbon. The indications were that "cortical dominance" in the chimpanzee is more complete than in the other primates studied, and in this respect the chimpanzee more closely approaches man. Removing the second (opposite) leg area in some of their primates, Fulton and Keller found that such an operation produced but little influence on the originally affected extremity in all of the monkeys excepting the baboon. This animal suffered definite and permanent impairment of motor power, as did the gibbon and the chimpanzee. This led them to conclude that baboon, gibbon and chimpanzee possess some degree of bilateral representation in the leg area, indicating that some of the corticospinal fibers to the lower extremity never cross.

While in the anthropoid apes a gradual and almost complete recovery from extirpation of the motor area takes place, in man the effects of destruction of the motor cortex are of far graver consequence. The results of ablation experiments in monkeys and anthropoid apes, correlated with the data from numerous cases of paralysis in human patients, show that in the ascending scale of the primates the motor cortex gradually takes over complete control of the voluntary movements and not merely their regulation. Through the fundamental investigations of Graham Brown and Sherrington (1912) it becomes clear that the reactions from the motor cortex are very complex and composite as compared with

decerebrate or purely spinal reactions (see further Hines, 1929, pp. 479-482). The data obtained are invaluable for a clearer understanding of the highly complex voluntary actions in man. A discussion of these problems is given by Leyton and Sherrington (1917, pp. 176-180; see also v. Monakow, 1914).

Sherrington and his co-workers have given special attention to the "echo-responses" from the postcentral gyrus. Grünbaum and Sherrington (1901/02) mentioned that in the anthropoid apes feeble reactions may under certain circumstances be obtained from the postcentral gyrus, especially through strong faradization. However, they emphasized the fact that these responses were equivocal and occurred under circumstances that exclude their acceptance as equivalent to motor reactions. Graham Brown and Sherrington later (1912) formulated this more clearly, stating that points in the postcentral gyrus, when stimulated immediately after cessation of a stimulus of a point of the precentral gyrus, are frequently able to elicit some return of the movement obtained just previously from the precentral convolution, producing, so to speak, an echo of the preceding response. But this dies out usually after the first repetition (see also Graham Brown, 1914; Leyton and Sherrington, 1917). Ablation of a large portion of the postcentral gyrus gave no paralysis, not even transitory (Grünbaum and Sherrington, 1901/02). Thus a chimpanzee, in which the postcentral convolution of the right cortex had been freely destroyed opposite the arm area, gave the hand at command ninety minutes after he came out of ether (Graham Brown and Sherrington, 1913).

Graham Brown, applying the method of rapid freezing of small points of the cortex with the aid of liquid air, then demonstrated (1914) that the activity of

the postcentral gyrus must be physiological and not due to spread of current to the corresponding section of the precentral gyrus (compare C. and O. Vogt), except in cases where too strong a current is used. He discussed the possible explanations of this peculiar phenomenon (Graham Brown, 1914, p. xxx). Thus it seems quite possible that the postcentral gyrus has a modifying influence on the corresponding directly excitable section of the precentral gyrus.

C. and O. Vogt (1906/07, p. 361) emphasized the fact that destruction of the postcentral gyrus in the monkey led to a decrease of the adequate characters of movements. The characteristic behavior of a monkey with the postcentral gyrus destroyed, in contrast with one in which the precentral gyrus was ablated, had previously been vividly portrayed by Brodmann (1905). Also, Lewandowsky and Simons (1909) noticed marked ataxia after removal of the postcentral gyrus, which they, however, attributed to sensory disturbances (compare on the other hand Leyton and Sherrington, 1917, pp. 209-210, 221).

That the electrically non-excitable precentral region has a direct modifying influence upon motor actions, becomes evident from the Vogts' additional observation that destruction of non-excitable precentral areas resulted in loss of certain complex limb movements (1906/07, p. 361). In human beings it has moreover been observed that disease of the frontal lobes causes a very striking reversion from the complex motor behavior to a more primitive behavior pattern, because lower mechanisms are released after damage to the dominating higher centers (Freeman, 1929).

The publication by Leyton and Sherrington (1917), giving a full account of the previous and additional, most extensive and most careful investigations of Sher-

rington and his co-workers, crowned the investigations on the motor cortex of the great anthropoid apes. This work includes the results and conclusions from experiments on 3 orang-utans, 22 chimpanzees and 3 gorillas. Thus the motor cortex of the great anthropoid apes has become the best known of the whole primate stock. The three great anthropoid apes seemed closely to resemble each other in regard to the motor cortex. But there were great individual variations and differences in the smaller details of localization of the right and left motor cortex of the same animal. The simpler examples of chimpanzee brains seemed inferior in development to well-developed examples of the brain of the orang, while in general the orang was found to be a little below the chimpanzee. The largest and most highly developed brain examined by Sherrington and his co-workers was that of a gorilla. The motor area in that specimen appeared to be, on the whole, the most extensive and most differentiated of those experimented upon (Leyton and Sherrington, 1917, p. 219).

In respect to the general development of the fore brain, some investigators place the orang-utan above the chimpanzee and the gorilla (compare e. g. Jacob and Onelli, 1911; Riese, '26; etc.). In more recent times the mentality of the chimpanzee has been studied by psychologists (Köhler, Yerkes, Kohts and others). The gorilla and the orang, on the other hand, less accessible and less coöperative in experimental work than the chimpanzee, are as yet little known and little understood. Some authorities, however, consider the orang to be of higher intelligence than either the chimpanzee or the gorilla.

In the orang-utan the facial area in relation to the rest of the motor area appears to be more extensive than in the other anthropoids (see figs. 16-18). It was found

to be considerably longer from above downward than in the chimpanzee and gorilla (Sherrington, 1906; Leyton and Sherrington, 1917). Apart from this distinction, there seem to be no clear differences between the motor areas of the three types of the big anthropoid apes (Leyton and Sherrington, 1917). That the motor cortex of the orang-utan would, at least to some extent, differ from that of the chimpanzee and of the gorilla, might be expected in view of the fact that in other organ systems the orang differs widely from his anthropoid cousins, the chimpanzee and gorilla, who closely resemble each other. This has been found most striking in a close comparison of the mimetic musculature of the three types (Ruge, 1887; Huber, 1931a). Renewed comparative studies on the motor cortex of the three big anthropoid apes may possibly bring out further differences.

d) Man

The first attempts to investigate the motor cortex of the human brain were made by Bartholow in 1874. He experimented with both faradic and galvanic currents, using insulated needle electrodes, which were applied to the dura mater and also inserted directly into the brain substance. Movements were obtained from the head, neck and extremities, but these responses were not referred to localized areas in the cortex.

In succeeding years a series of reports of more exact observations were published by various authors, chiefly by American neurologists and surgeons, among which those of Keen, Lloyd and Deaver, and Mills are notable for the exact manner in which faradization was used, as early as 1888, as an aid in localizing the motor area of the cortex in connection with brain surgery. In 1897, Lamacq published an important paper on the motor cortex of

the human brain, including a discussion of the observations of previous workers. More recently, most valuable contributions to our knowledge of the excitable human cortex have been made by Krause (1904, '05), Mills and Frazier ('05), Cushing ('09), van Valkenburg ('14), and Foerster ('26, '31) (see figs. 19 and 20).

Encouraged by the experiments of Grünbaum and Sherrington upon anthropoid apes, Krause (1904, '05) stimulated a number of human brains by unipolar faradization. He stressed the fact that, owing to the great variability of the pattern of the convolutions, pure anatomical orientation with a comparatively limited exposure of the cortex (arachnoid and pia mater being intact) is impossible. He warmly advocated the physiological method of electrical stimulation as the only means of exact localization in the operative treatment of Jacksonian epilepsy.

Mills and Frazier (1905) independently followed the same line of work, for the most part using unipolar faradization upon anesthetized patients.

Later Cushing (1909) and van Valkenburg (1914) presented most valuable data obtained from patients whom they had stimulated by the unipolar method in the conscious state. Their observations give evidence that in man the electrically excitable motor and the sensory areas are separated by the sulcus centralis. This, however, does not necessarily lead to the conclusion that the motor and sensory areas are so sharply separated in a physiological sense. There is evidence that even in man the sensory area extends in front of the sulcus centralis into the motor area. This has been convincingly demonstrated in the macaque (*Macacus rhesus* and *M. nemestrinus*) by Dusser de Barenne (1924). Van Valkenburg, moreover, found that the sensible points for given parts of the body in the postcentral gyrus lie exactly parallel

to the corresponding motor points in the precentral gyrus (compare also Foerster, 1931; and fig. 20). This characteristic arrangement is probably not solely due to a physiological coördinating influence of cortical sensibility upon motion (v. Valkenburg), but is presumably determined through morphological segregation of the motor and the sensory areas in the higher mammals by gradual evolution from a less differentiated sensory-motor area typical of the primitive mammalian ground-plan. Extensive comparative investigations on cortical localization by Brodmann strongly suggest such evolution.

Foerster (1926) studied the motor cortex in connection with operations on epileptics. A more recent report of his work (1931) is of great importance (see fig. 20). He stimulated patients under local anaesthesia with threshold galvanic stimuli and under general anaesthesia with faradic current. In order to obtain circumscribed effects he found it essential that the cortex be dry and that the stimuli be of threshold strength. The threshold of the foci varied from one individual to another. He classified the motor areas of the cortex as pyramidal (corticospinal) and extra-pyramidal. The pyramidal area is confined to area 4, whose cells give rise to the fibers of the corticospinal tract. This area lies chiefly in the central sulcus and also in the precentral gyrus. It is the specific region for isolated innervations. Stimulation of points in this area produces isolated movements of a single segment of the limbs or of a single portion of the trunk or head, usually contralateral. Representation of the upper portion of the face, pharynx, vocal cords and masticatory musculature is bilateral. Stimulation of the trunk and thigh areas also occasionally produces bilateral movements of these parts. Movements of the sternocleidomastoid and external pterygoid muscles

are ipsilateral. There are separate foci for each finger. Separate innervation may be distinguished not only for single groups of muscles but likewise for individual muscles as well. When area 4 or the corticospinal tract is destroyed, isolated movements are no longer performed, yet voluntary movement is by no means completely abolished. In such a lesion the individual is still able to perform complex flexor or extensor movements of the affected limbs, but the movements are combined (e.g. in spastic tetraplegia voluntary movement of a single limb also produces movements of the other three extremities). Such movements arise in the extrapyramidal areas (6aB, 5a, 5b, 22, 6aA, 3, 1, 2). These regions do not give rise to fibers of the corticospinal tract, but are connected to subcortical and other lower centers; they are the areas for "adversive" and complex synergic movements which are in marked contrast to the isolated effects obtained from area 4. As long as the pyramidal system (area 4 and the corticospinal tract) is intact, stimulation of extrapyramidal areas 6aA and 3, 1, 2 produces isolated effects similar to those obtained from area 4, but Foerster showed that these movements are due to spread to area 4 (this is made clear by cases of Jacksonian epilepsy or by epilepsy resulting from lesions of the precentral gyrus consequent to destruction of the corticospinal tract, and by isolating area 4 by cortical incision or superficial abrasion of area 6aA). It is interesting to note that area 6aA in man occupies the greater portion of the summit of the precentral gyrus, whereas in monkeys, according to Foerster, it lies in the frontal convolution. It is likewise noteworthy that areas 3, 1 and 2, which Foerster ascribes to the extrapyramidal system, are located in the somæsthetic area, which lies in the post-central gyrus. Foerster concluded that both pyramidal and extrapyramidal areas

coöperate in the performance of voluntary movements, but that isolated effects arise only from the pyramidal area (area 4). This area therefore is to be regarded as the "motor cortex" as defined in this paper. In respect to its location and subdivision Foerster's investigations confirm and extend the results of previous workers on man.

For obvious reasons, these experimental data obtained from man cannot be as complete as those produced from experiments upon other animals. It is important that the results so far obtained closely correspond to the findings from the more numerous and more complete experiments on the anthropoid apes. The true motor (pyramidal) area of the human cerebral cortex lies in the region anterior to the sulcus centralis Rolandi, a large portion, as in the apes, forming the walls of this sulcus. The localization clearly follows the plan in other primates, the hind limb area bordering the superior longitudinal fissure, with the head area adjoining the fissure of Sylvius (see figs. 19 and 20). The results obtained from stimulation are in accord

with studies on the cyto-architecture of the human and anthropoid cortex (Campbell, 1905; Brodmann, '09; v. Economo and Koskinas, '25) and with localization of the cells of origin of the corticospinal tract (Holmes and May, 1909).

Hines (1929), after considering the data obtained from stimulation, ablation and accidental lesions, concluded that

in spite of the great similarities of the motor cortex in ape and in man the importance of its intactness for the maintenance of normal posture in the latter is apparently greater . . . Seemingly the motor cortex presides over fine individual movements, especially of the extremities. It regulates the distribution of tone in opposing muscle groups. It exerts apparently a certain restraint on reflexes and associated movements. It integrates, or perhaps interprets, certain incoming impulses which are necessary for the coördination of movements and movement sequence. Moreover, it facilitates, augments and aids in gauging the amount of contraction of individual muscles or groups . . . The motor cortex may not be the site of origin of voluntary movement nor the gate through which learned movements pass, but certainly it assures to man that his muscular adjustments take place in the way to which he is accustomed and without undue effort or strain.

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FIGS. 1-7. LEFT CEREBRAL HEMISPHERES OF VARIOUS MAMMALS, SHOWING THE ELECTRICALLY RESPONSIVE AREAS OF THE CORTX

The figures, having been taken from different sources, are not drawn to the same scale. They therefore are not indicative of relative size in comparison to one another.

FIG. 1. Duckbill platypus (*Ornithorhynchus anatinus*). (According to experiments by Martin, 1898/99.) Side view. In this animal facial and fore limb areas partly coincide, while hind limb and tail areas are absent.

FIG. 2. Opossum (*Didelphys virginiana*). (Modified after Weed and Langworthy, 1925, and other authors.) Side view. The undisputed motor areas border on the orbital sulcus.

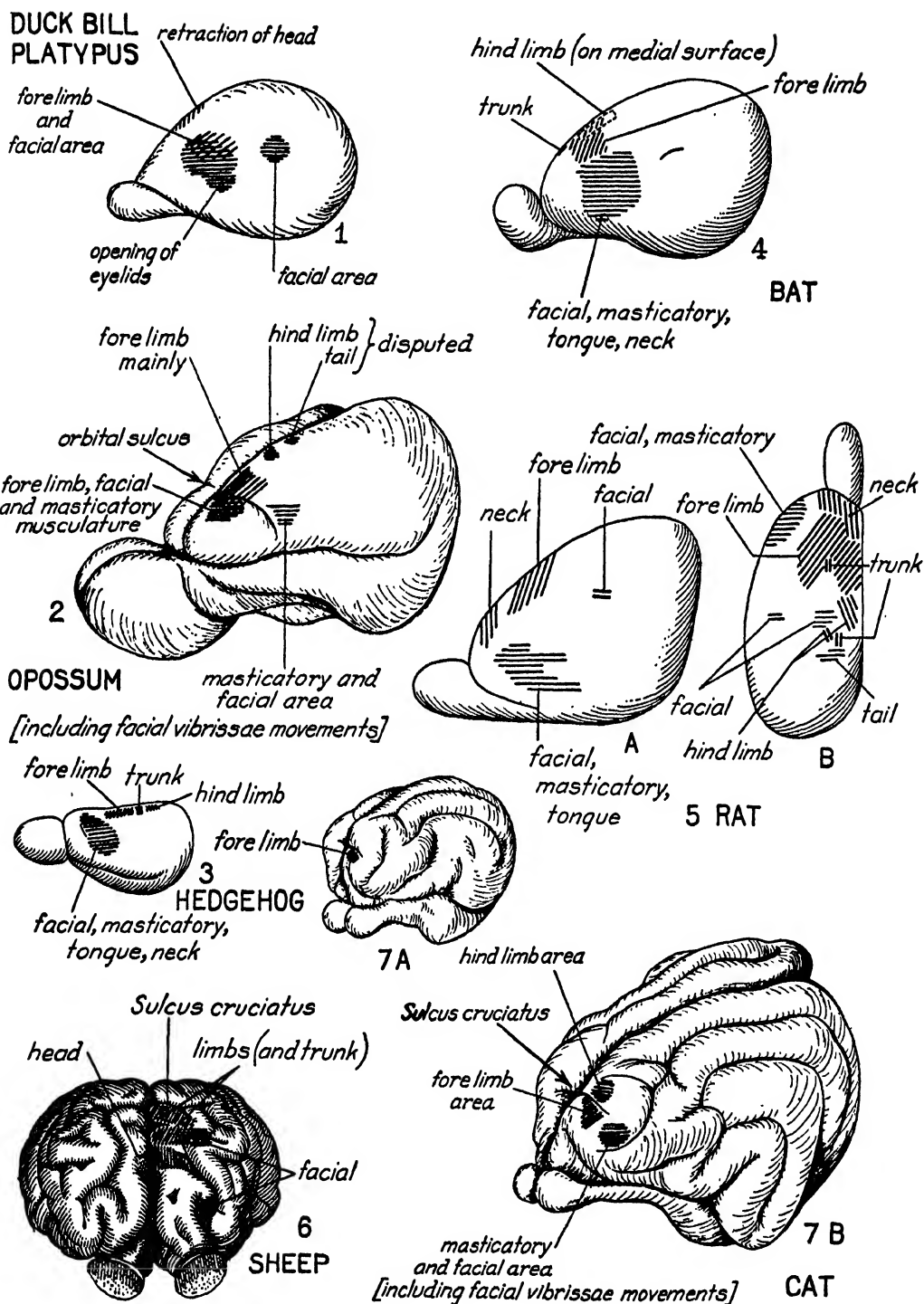
FIG. 3. Hedgehog (*Erinaceus europaeus*). (After C. and O. Vogt, 1906/07.) View from the side and slightly from above.

FIG. 4. Bat (*Pteropus Edwardsi*). (After C. and O. Vogt, 1906/07.) Side view. The inconstant hind limb area is located on the inner surface of the hemisphere.

FIG. 5. Rat (*Mus rattus*). (After Lashley, 1921.) A.—Side view. B.—View from above.

FIG. 6. Sheep (*Ovis*). (After Bagley, 1922.) Brain seen from in front, with electrically responsive areas charted on left hemisphere only.

FIG. 7. Cat (*Felis domestica*). A.—Newborn kitten (after Weed and Langworthy, 1926). Side view. At this age the only responsive area is that of the fore limb, which has the same location as in the adult cat. B.—Adult cat (after Weed and Langworthy, 1926, and after unpublished observations by Huber and Smith). Side view. The electrically responsive areas are grouped about the cruciate sulcus, an arrangement characteristic of carnivores.



FIGS. 1-7

FIGS. 8-15. LEFT CEREBRAL HEMISPHERES OF PROSIMIANS, PLATYRRHINE AND CATARRHINE MONKEYS, AND GIBBONS,
SHOWING THE ELECTRICALLY RESPONSIVE AREAS OF THE CORTEX

The figures, having been taken from different sources, are not drawn to the same scale. They therefore are not indicative of relative size in comparison to one another.

FIG. 8. Lemur (*Lemur macaco*). (After C. and O. Vogt, 1906/07.) Side view. The motor cortex lies in front of a small sulcus which possibly foreshadows the central sulcus of monkeys, apes and man.

FIG. 9. Potto (*Perodicticus potto*). (After C. and O. Vogt, 1906/07.) Side view. The motor cortex is situated in front of sulcus "cc," possibly homologous to the central sulcus of simians.

FIG. 10. Marmoset (*Callithrix*). (After C. and O. Vogt, 1906/07.) Side view. The lissencephalic hemisphere has no suggestion of a central sulcus. The motor area, however, exhibits the same topographic relations as in those monkeys which possess a well defined central sulcus. The cortex is differentiated histologically (Brodman, 1909). In the phylogeny of the primate cortex the development of the cyto-architecture precedes the formation of the sulci and gyri.

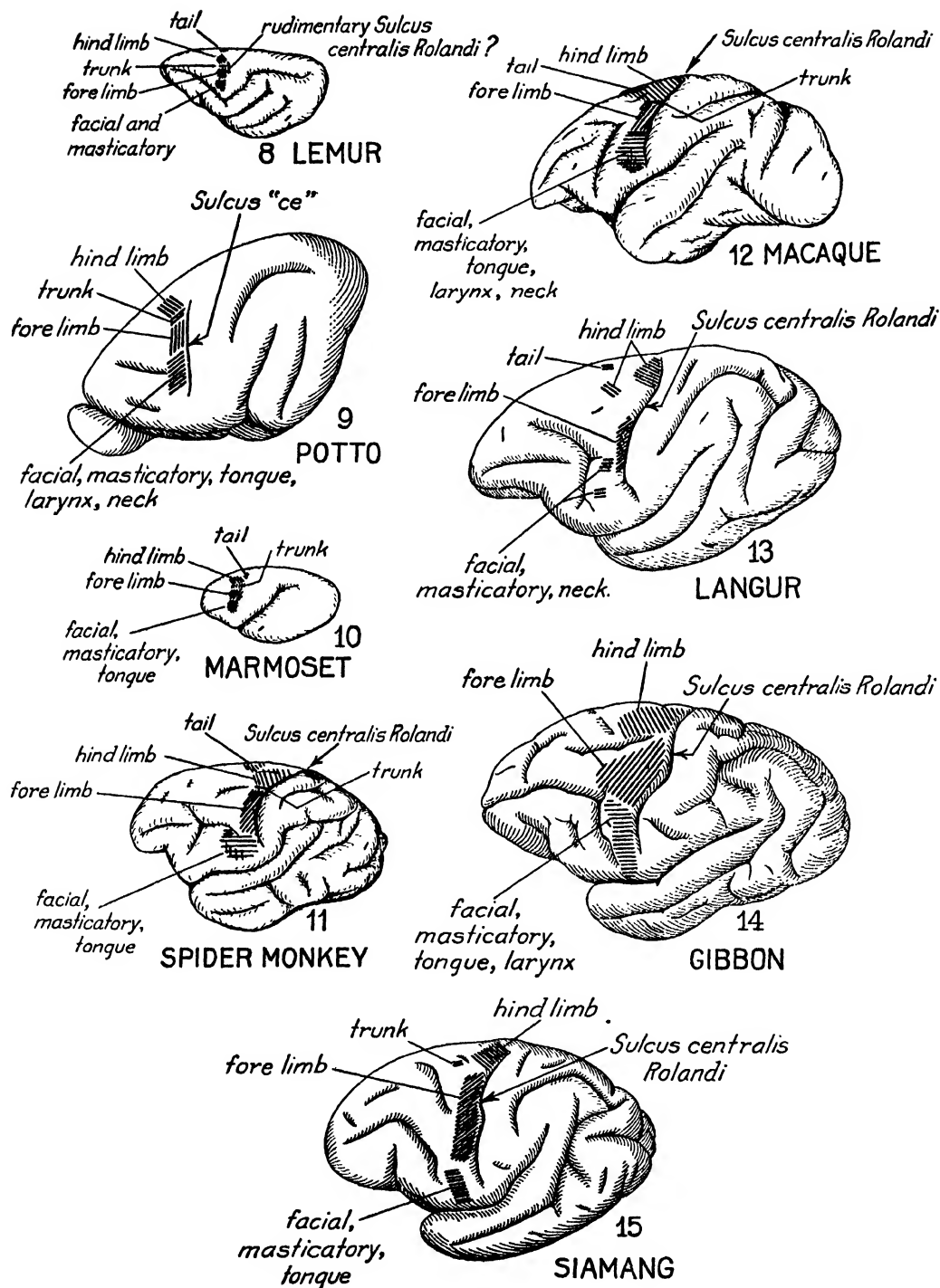
FIG. 11. Spider monkey (*Ateles ater*). (After C. and O. Vogt, 1906/07.) Side view. The central sulcus, as in the catarrhines, is well-defined, and it marks the posterior border of the motor cortex. The prehensile tail is well represented.

FIG. 12. Macaque (*Pithecus*). (Combined drawing from stimulation experiments by various authors, including unpublished observations by Huber and Smith.) Side view.

FIG. 13. Langur (*Simnopithecus* (= *Pygathrix*) *entellus*). (After C. and O. Vogt, 1906/07.) Side view.

FIG. 14. Gibbon (*Hyllobates*). (After Mott, Schuster and Sherrington, 1911.) Side view. The fore limb area is well-developed, and is expanded forward into the middle frontal convolution.

FIG. 15. Siamang (*Symphalangus syndactylus*). (After C. and O. Vogt, 1906/07.) Side view. The fore limb area is relatively huge in its extent.



FIGS. 8-15

FIGS. 16-20. LEFT CEREBRAL HEMISPHERES OF GREAT ANTHROPOID APES AND MAN, SHOWING THE ELECTRICALLY RESPONSIVE AREAS OF THE CORTEX

The figures, having been taken from different sources, are not drawn to the same scale. They therefore are not indicative of relative size in comparison to one another.

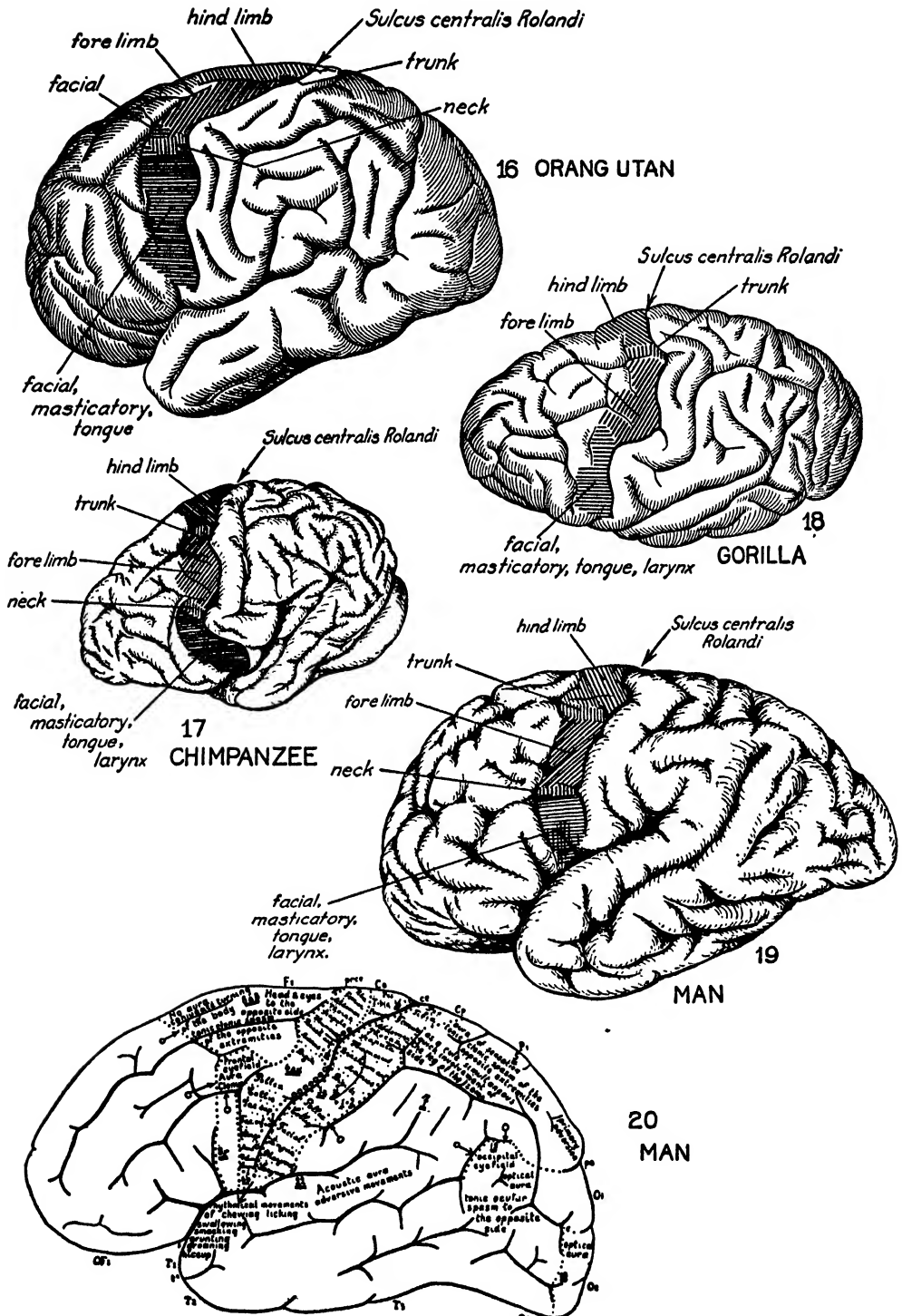
FIG. 16. Orang-utan (*Pongo pygmaeus*). (After Leyton and Sherrington, 1917.) Side view. The head area is relatively larger than in the other anthropoid apes.

FIG. 17. Chimpanzee (*Pan*). (After Grünbaum and Sherrington, 1901/02.) Side view.

FIG. 18. Gorilla (*Gorilla gorilla*). (After Leyton and Sherrington, 1917.) Side view.

FIG. 19. Man. (Outline from Spalteholz' atlas, with results of stimulation experiments by Krause, Mills and Frazier, Cushing, van Valkenburg, etc. superimposed.) Side view.

FIG. 20. Man. (After Foerster, 1931.) Side view. Area 4 represents the true motor field (pyramidal area). The extrapyramidal areas are numbered 6aB, 5a, 5b, 22, 6aA, 3, 1 and 2.



FIGS. 16-20



NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of THE QUARTERLY REVIEW OF BIOLOGY, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

BRIEF NOTICES

EVOLUTION

OLDOWAY, DIE SCHLUCHT DES URMENSCHEN. *Die Entdeckung des altsteinzeitlichen Menschen in Deutsch-Ostafrika.*

By Hans Reck. F. A. Brockhaus, Leipzig.
8.70 marks (paper); 10.50 marks (cloth).
6 x 9; 308; 1933.

In 1911 a Dr. Kattwinkel of Munich, while on a hunting expedition into that part of German East Africa which is now incorporated into Tanganyika Territory, happened upon the Oldoway gorge, found there a rich deposit of fossil bones, and brought several back with him to Germany. Two years later Dr. Reck headed an expedition, sponsored by the Geological-Paleontological Museum of the University of Berlin, to explore these deposits further and to study the geological structure of the gorge and the desolate and volcanic region surrounding it. The work was cut short by the World War, the service of the author in the army, and his retention as prisoner in Egypt. After German East Africa became English territory much of Dr. Reck's material was transferred to England for study. In 1931 Dr. Reck and Mr. Hopwood, of the British Museum, were invited to join the East African Archaeological Expedition, headed by Dr. Leakey of Cambridge University. This book gives an interesting and graphic account of the two expeditions—the hardships of travel, methods of work and results. Oldoway proved to be a good hunting ground for a paleontologist with its vast profusion of bones of prehistoric animals—three-toed horses, hippopotami,

etc.—and man. The most important find was the Oldoway skeleton, the skeleton of a man of the diluvial period, who was more highly developed than the Neanderthal man and knew how to fashion instruments for his use from wood, quartz, obsidian and lava. In one chapter the author attempts to reconstruct the surroundings and life of this period. His opinion is that the eruption of a volcano caused a mass destruction of the inhabitants and the paradise in which they lived.

The book is equipped with an index, numerous photographs and drawings, and a map. It will interest the general reader as well as the paleontologist.



CONCEALING COLORATION AMONG SOME DESERT RODENTS OF THE SOUTHWESTERN UNITED STATES. *University of California Publications in Zoology, Vol. 40, No. 1.*

By Seth B. Benson. *University of California Press, Berkeley.* \$1.25. 6 $\frac{3}{4}$ x 10 $\frac{1}{4}$; 69; 1933 (paper).

A field study of the distribution of mammals inhabiting the Tularosa Basin of southern New Mexico, particularly an area of white sand dunes and black lava flow, shows that only those mammals which tend to be isolated on these areas parallel them in color. Not all races exhibit the same degree of pigmentation nor is the range of variation within the race the same, but there is a definite departure from the normal. The author reaches the conclusion that

The hypothesis of the operation of natural selection toward producing protective coloration, together with the factor of isolation, appears to be the best explanation of the development of the races peculiar to the dunes and to the lava.

The extremely wide range of variation present in some of the races inhabiting these special areas is probably due to the fact that the barriers which enclose them are not impassable, even to animals which tend to be restricted to dunes and [or] rocky places, thus allowing "normal" individuals from the surrounding area to intermingle and interbreed with the peculiar races. It is possible, however, that the wide range of variation may mean that selection has not yet established a constant race.

The study includes a general account of mammals present in the lower parts of the Tularosa Basin, meteorological data of the region and detailed descriptions of the important features of the lava beds and sand dunes, with illustrations. There is also a literature list of 49 titles and a number of figures and plates.



EVOLUTION AND REDEMPTION.

By H. P. Newsholme. *Williams and Norgate, London.* 8s. 6d. net. $4\frac{7}{8} \times 7\frac{1}{2}$; 267; 1933.

This book sets forth a very pious version of Lamarckism. In the beginning God created spirits, to whom He gave "freedom to attain expression of themselves, and thereby of God from Whom they were derived, through a material created out of their own substance." By misuse of their freedom, either from cowardice or from self-will, these spirits introduced a bias into matter, which manifests itself as inertia, death, sin, disease and suffering. Evolution has been a process of casting off this inertia. Those organisms whose strivings were in harmony with the immanent divine element developed along the main track of evolution, while those which were motivated by cowardice or self-will diverged into blind alleys. But even in the main line of evolution the bias of inertia still clung to matter. It was therefore necessary that the Creative Spirit should become Man, should take upon Himself and overcome inertia.

In his discussion of the Virgin Birth the author concludes that "The irruption of the spiritual through the material, in breaking the inertia of the latter may

break also the uniformity of natural law." But is there any need of assuming a break in natural law? We are informed by a medical friend, formerly an interne in a New York obstetric ward, that a considerable proportion of the unmarried mothers delivered there state that theirs is a case of virgin birth. If then human parthenogenesis is a not uncommon phenomenon in the twentieth century, need we interpret its occurrence in the first century as miraculous?



TROIS PROBLÈMES: L'ESPÈCE—L'INSTINCT—L'HOMME: *L'Allure du Développement, Critérium d'Espèce; La Synergie Fonctionnelle Automatique, Source de l'Instinct; l'Homme, Anthrope Ralenti de Développement.*

By Émile Devaux. *Librairie E. Le François, Paris.* 25 fr. $6\frac{3}{4} \times 10$; xii + 350; 1933 (paper).

The ideas of Darwin, Lamarck and others are freely borrowed in this book which according to the author expresses a novel view of evolution. His theory is founded on the fact that each species has a different rate of development (*allure du développement*). A change in this rate causes mutation and is due to hunger and other physical hardships which affect the organism and the sexual organs in particular, and through these the germ cells. The slower the rate of development, prenatal especially, the higher in the scale of evolution rises the animal. Man is thus an animal with retarded development, but he is superior to the others with equal or slower rates because of the preponderance of the brain and nervous system.

The object of this book is to present this theory in the hope that experiments be undertaken to prove or disprove it.

The naïveté of the writer is refreshing indeed. After all, why build a theory on arrays of statistics, experiments or multiple observations when ingenious inferences satisfy the author just as well?



STUDIES OF THE PLIOCENE PALAEOBOTANY OF CALIFORNIA. *Contributions to Palaeontology, Carnegie Institution of Washington Publication No. 412.*

Carnegie Institution of Washington, D. C.

6 $\frac{1}{2}$ x 10; 134 + 18 plates; 1933.

The first and longer paper in this volume is on *Pliocene Floras of California*. Erling Dorf reports fossil plant remains of 34 species taken from 16 localities. Ten of these localities are less than 35 miles from San Francisco Bay, the other six at much farther points to the north and south. The formations in which they occur are of lower to middle Pliocene age. The occurrence of the plant bearing horizons within each of the various formations is treated in detail. The study is documented and indexed.

The second paper is on *Woods from the Ricardo Pliocene of Last Chance Gulch, California* by Irma E. Webber. This is based on a field and laboratory study of petrified wood. The species represented are all similar to or possibly identical with those now living in the southern United States. Both papers are excellently illustrated.



EVOLUTION OF HABIT IN BIRDS.

By Edmund Selous. Constable and Co., London. 10 shillings net. 5 x 7 $\frac{1}{2}$; xvi + 296; 1933.

The author writes of such matters as formalization and the disappearance of the fighting instinct, nest-building, sexual display, landed proprietorship, domestic cleanliness, parental care, song, and the storing habit of the California woodpecker. But his ideas and discussions of their origin and development are essentially similar to those of the Romanes-Haeckel-Weismann era. Many detailed observations taken from field notes on a variety of species of birds are offered to illustrate the conclusions. The book is written in the author's usual charming, though at times difficult, style. The index is adequate, well-prepared, and, one might say, as interestingly written as the rest of the book.



THE PRINCIPLES OF HISTORICAL GEOLOGY FROM THE REGIONAL POINT OF VIEW.

By Richard M. Field. Princeton University Press, Princeton, N. J. \$3.50. 6 x 9; xii + 283 + 10 plates; 1933.

The plan on which this textbook is laid out is to introduce students to the working methods of historical geology by discussing in turn six regions, the Grand Canyon, Niagara Falls, the Appalachians, the Northwest Highlands of Scotland, the Alps, and the Yellowstone Park, beginning with localities in which the succession of geological events is easily traced and proceeding to more obscure situations. The biological aspect is largely omitted. The illustrations are block diagrams and topographical maps and they include drawings of relief maps of the regions described. Interest has been added by notes on the adventures of the pioneer geologists who worked in these regions and by an entertaining chapter on the history of stratigraphy. It can be recommended to anyone interested in "the scientific interpretation of scenery" and to scientifically-minded tourists.



MERKMALE UND GRENZEN IN DER DOMESTIKATIONSFRAGE AM GEBISS. *Deutsche Zahnheilkunde* Heft 84.

By Heinrich Fabian. Georg Thieme, Leipzig. 8 marks. 6 $\frac{1}{8}$ x 9 $\frac{1}{2}$; 99; 1933 (paper).

Although most of the defects of teeth and jaws of wild and domesticated animals considered in this summary of the comparisons made by the author and others, were found to be more prevalent in the domesticated forms, animals living in the wild may, and do, acquire such defects under certain conditions, e.g. scarcity of necessary food elements. *Ergo*, the author concludes that it is not domestication itself or the length of time involved that is essential. It is rather the manner in which it has been carried out, from environmental and dietary points of view. The book is provided with a bibliography of 3 pages and many excellent photographs.



PHYLOGENESE UND GESCHWULSTENTSTEHUNG.

By Max Glogner. Johann Ambrosius Barth, Leipzig. 1.60 marks. 6 x 9 $\frac{1}{2}$; 32; 1933 (paper).

A presentation of the author's theoretical

views on the etiology of malignant tumors. On the basis of experimental studies on the heredity of malignant disease, the changes in its development, and the similar behavior, morphologically and physiologically, of protozoan and malignant cells, the author favors the phylogenetic theory according to which the malignant cells are thought to be descended from the protozoan cells from which the early multicellular organisms are held to have been formed. Although most of these cells are transformed into metazoan cells some retain protozoan characteristics, and thus the protoplasm of malignant cells has been transmitted continually, from the earliest times of organic life, by the germinal substance of the sex cells. The brochure lacks index and bibliography, and, we venture to think, probatory cogency.



TELEOLOGICAL FACTORS IN EVOLUTION. Function Determines Structure. *A Thesis Presented to the Faculty of the American University Graduate School in Partial Fulfillment of the Requirement for the Degree of Doctor of Philosophy, Washington, D. C., 1932.*

By Leon A. Fox. [Limited number of copies for free distribution; apply to Major Leon A. Fox, Room 3050 Munitions Bldg., Washington.] 6 x 9; ix + 71; 1933 (paper).

This doctoral thesis reviews the factors that have been suggested as responsible for evolution. The author concludes that mutations and chance variations do not furnish sufficient grist for the mill of natural selection and that purposeful adaptations must be postulated to account for the facts of evolution. He is inclined to interpret the inheritance of diabetes, refractive errors and glaucoma and the development of the trotting horse as examples of the inheritance of acquired characters. Whereas formerly it took years of training to develop a trotter, nowadays trotters are born, not made. There is a bibliography of four pages but no index.



THE LONG ROAD. From Savagery to Civilization.

By Fay-Cooper Cole. *The Williams & Wilkins Co., Baltimore.* \$1.00. 5 x 7½; xi + 100; 1933.

Besides its display at Chicago of the tangible fruits of the past hundred years of scientific and technical development the Century of Progress Exposition is sponsoring a series of books presenting in brief our present-day knowledge of the various sciences. In this number of the series one of the leading American anthropologists tells the story of the long ascent from *Pithecanthropus* to modern man, the physical and cultural development that has taken place, and the differentiation of modern races. The book contains a bibliography of two pages, but no index. It is illustrated with reproductions of the admirable murals in Logan Museum, Beloit College, showing various stages of culture.



CONODONT STUDIES Number 1 and Number 2. The University of Missouri Studies, Vol. VIII, Nos. 1 and 2.

By E. B. Branson and M. G. Mehl. *University of Missouri, Columbia.* \$1.25 each. 7½ x 10½; 167 + 12 plates; 1933 (paper). Conodonts (fossil teeth supposedly from primitive fishes) are treated taxonomically in these studies to make them more useful as geologic horizon markers. A short introductory section gives methods of handling the material for study. Then follows the classification under subheads corresponding to sources of the material. Each section is supplemented with plates illustrating the species characters. The value of conodonts as horizon markers lies in the favorable possibilities for correlation in wide-spread forms, the short vertical range of species, and the hardness of the material.



THE WORLD OF FOSSILS.

By Carroll L. Fenton. *D. Appleton-Century Co., New York.* \$2.00. 4½ x 7½; x + 183; 1933.

A book that will interest the general reader. The author discusses fossil forms, from the earliest known creatures of the

water to mammoths and men, as the "remains of living organisms which had work to do, problems to solve and emergencies to meet . . ." The volume is illustrated with figures and maps, and contains a section on references and collections, a glossary, and an index.



GENERAL BIOLOGY

HVALRÅDETS SKRIFTER. *Scientific Results of Marine Biological Research. Nr. 7. Essays on Population.*

Edited by Universitetets Biologiske Laboratorium. Jacob Dybwad, Oslo. 7 x 10 $\frac{3}{4}$; 152 + 6 plates; 1933 (paper).

These studies emanate from the Biological Laboratory at Oslo, Norway. They are concerned with the report of investigations primarily related to the whaling industry. The task has been approached with intelligence, however, in that the authors have not hesitated to draw upon other forms for illustrative purposes as well as to delve into theoretical matters where needed. The present volume (the seventh in the series) is constituted by five separate essays. These are,

1) Johan Hjort: Whales and Whaling. 2) Per Øttestad: A mathematical method for the study of growth. 3) Alf Klem: On the growth of populations of yeast. 4) Johan Hjort, Gunnar Jahn and Per Øttestad: The optimum catch. 5) Norwegian Pelagic whaling in the Antarctic. II.

The first article on whales and whaling may be recommended as an interesting natural history report on the types of whales and their habitat relationships. The third paper on yeast growth attempts to analyze the general dependence of growth upon the means of subsistence, and the poisonous waste-products which develop with increase of population size. This paper, representing an abundance of experimental work, may well be called to the attention of yeast workers. In the essay on the "Optimum Catch" the primary problem of the volume is developed. Simply put, this problem is: how can the populations of the seas, specifically whale and fish populations, be exploited to a maximum degree and still not be in danger of extinction? The authors present data

showing how some populations are affected by natural and human toll along with reserved propaganda for international rules and regulations on the whaling industry.

This book may well be drawn to the attention of biologists and represents a distinct contribution to the literature on population. The text seems not to have been carefully proof-read since various typographical errors occur including occasional misspellings. The essays are all in English.



THE UNIVERSE AND LIFE.

By H. S. Jennings. Yale University Press, New Haven. \$1.50. 5 $\frac{1}{8}$ x 8; 94; 1933.

This small volume represents a formal contribution to the philosophy of life and the universe. The book, to a biologically-minded reviewer at least, has the attribute of being clear and understandable when compared to the frequent and often enigmatical writings of the physical scientists. The subject matter is treated under the three following divisions: the nature of the universe as revealed by the study of biology, the nature of evolutionary progress, and the management of life. A fundamental thesis of the philosophy is that the universe, at first lifeless, later produces life through its own activities and with this production a new universe is created which, " . . . begins to become conscious of itself, begins to feel, to think, to have ideas and purposes and ideals." In other words, in giving rise to mental processes new things arise in the universe which are only known as they occur and are experienced. The author also points out that life is moving onwards; following a new course towards a non-existing and non-predictable goal.

A stimulating book.



CYTOLOGICAL TECHNIQUE.

By John R. Baker. Methuen and Co., London. 3s. 6d. net. 4 $\frac{1}{8}$ x 6 $\frac{1}{4}$; xi + 131; 1933.

Professor Baker has written briefly and

interestingly on the technique of making cytological preparations of animal cells, on the chemical and physiological properties of the important reagents and stains, and on the development of the standard techniques, and, everything considered, has been able to say a good deal in this little manual. As he puts it the

guiding principle has been to give as few methods as possible, and to describe them in great detail, with full information as to the nature of the reagents used. It has been my object to tell the student throughout what he is doing, so far as is possible in such a difficult subject. All irrational methods, with which the literature abounds, have been carefully avoided. Many investigators have published formulae for fixatives and other fluids, without giving any indication of the researches which have led up to them. They have given no concrete evidence of why they are to be preferred to other fluids, nor of whether various proportions of the substances used were tried, with what results.

The use of this handbook ought to lead to more critical use of cytological methods on the part of students and it might serve to stimulate research on the methods themselves by more advanced workers.



HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 413. Allgemeine vergleichende Physiologie.* Containing following articles: *Das nasse photographische Kollodiumverfahren im Dienste des Biologen*, by Carl J. Cori; *Methodik der biologischen Lichtwirkungen*, by Ludwig Pincussen; *Über die Methoden zur Konstanthaltung von Temperatur und Luftfeuchtigkeit im biologischen Laboratoriumsversuch*, by Ernst Janisch.

Urban und Schwarzenberg, Berlin. 5.80 marks. 7 x 10; 112; 1933 (paper).

Cori claims a greater sharpness of photographic detail and less expense for a moist collodion plate method used in commercial photography, and describes his method for preparing and handling the plates.

Pincussen covers several phases of the new developments in his subject; his descriptions of equipment include the newer types of light sources whose radiation is limited to narrow spectral bands, thermocouples, and photoelectric cells. He devotes about 30 pages to methods of studying light reactions of plants and animals. Lunz contributes a chapter on a large spec-

troscope with two prisms for producing monochromatic light.

Janisch discusses the elementary principles that ought to govern the selection and care of constant temperature apparatus describing little niceties of technique. He takes up some simple methods of humidity control that make use of the vapor pressure of known concentrations of salt solutions, presenting tables showing the relative humidity of air in equilibrium with certain solutions at different temperatures.



ÜBER ENTSTEHUNG UND ENTWICKLUNG DES LEBENS.

By Fr. Samberger. *Leopold Voss, Leipzig.* 2.40 marks. 5 x 7½; 55; 1933 (paper). The author, director of the dermatological clinic of the University of Prag, sets forth in this booklet a theory of evolution based on an alleged principle that higher organisms, including man, developed from lower forms of their own special protoplasm and not from lower organisms, as assumed by the current theories. Accordingly, all life has passed first through its "premiere" of evolution in which the original types of all individuals developed from the specific original cells of their genus. Man, therefore, he concludes, was formed not through phylogeny but through anthropogeny, as witnessed by the naevi and all atavisms in man. The author sees the source of the whole development of all living matter in an inner striving after the optimum of existence; the evolutionary transformations of living matter flow from its own initiative activity and are by no means the mere consequence of the passive adaptability to outer stimuli, as assumed by Lamarck, Darwin and Roux. The book lacks index and bibliography. [Reginald, our procacious Office Boy, says that the only biologists likely to be influenced by this treatise are God and Bernard Shaw.]



JUNGLE MEMORIES.

By Henry H. Rusby. *Whittlesey House, McGraw-Hill Book Co., New York.* \$3.50. 5½ x 9; xiii + 388; 1933.

Professor Rusby recounts the story of his expedition in 1885-87 to South America in search of coca and other medicinal plants. Across the Andes, through the jungles of the Beni, Madeira and Amazon valleys he traveled using the most primitive means of transportation. The strength of his personality is evident in every page, as in a nonchalant manner he briefly relates some mortal peril evaded or difficulty overcome. His almost daily adventures did not deflect him from the scientific objective of his expedition and he continuously noted and collected plants and animals. A description of the flora and fauna of those regions he has given in his scientific publications but what is mentioned here is sufficient to emphasize the richness of life there. We suggest that this book should be read in connection with that classic of Amazonian travel literature, *White Waters and Black*.



ELEMENTS OF BIOLOGY *With Special Reference to Their Rôle in the Lives of Animals.*

By James W. Buchanan. Harper and Brothers, New York. \$3.00. $5\frac{3}{8}$ x 8; xx + 478, 1933.

This textbook has been designed with the liberal arts student in mind: "the content of the volume includes the understanding and information that the intelligent layman might reasonably be expected to have as the result of his experience in a general course." The arrangement follows in the main the conventional type of general biology textbooks but more references to man are included and a greater use of small mammals as laboratory material is suggested. The book concludes with a glossary and an adequate index, and suggested reading lists are given at the end of each chapter. The illustrations are for the most part new or redrawn.



THE ASSOCIATION OF THE TERMITES, *KALOTERMES MINOR*, *RETICULITERMES HESPERUS*, AND *ZOOTERMOPSIS ANGUSTICOLLIS* WITH FUNGI. *University of California Publications in Zoology*, Vol. 39, No. 5.

By Esther C. Hendee. *University of Cali-*

fornia Press, Berkeley. 30 cents. $6\frac{3}{4}$ x $10\frac{1}{4}$; 24; 1933 (paper).

Representatives of 33 genera of fungi were isolated from the colonies of three species of termites of diverse habitat. No fungus appeared to be peculiar to any one termite species, and *Penicillium* and *Trichoderma* were isolated from each. Neither was there any specificity as far as the wood was concerned, and it appears that the termites carry spores about with them. No decision was reached as to whether the fungus makes wood more available or more attractive to termites.



THE BIOLOGY OF THE PROTOZOA. *Second Edition. Thoroughly Revised.*

By Gary N. Calkins. Lea and Febiger, Philadelphia. \$7.50. $5\frac{3}{4}$ x $9\frac{1}{2}$; xi + 607; 1933.

Previous mention has been made in these pages of the first edition of this very excellent standard textbook. The present edition has been thoroughly revised and rearranged. It emphasises the conception of a changing organization brought about by continued metabolism. This conception "furnishes the basis for an interpretation not only of life histories but of the significant biological phenomena of cell division, maturity, sex differentiation, fertilization and senescence as well." There are new sections on parasitism and disease. Reference to protozoan flagellates has been limited to the Zoömastigophora. The bibliography has been brought up to date.



NEW INTRODUCTION TO BIOLOGY.

By Alfred C. Kinsey. J. B. Lippincott Co., Chicago. \$1.68. $5\frac{1}{4}$ x $7\frac{1}{2}$; xxiii + 840; 1933.

The review of the first edition (noticed in Volume 2 of this REVIEW) considered it particularly noteworthy because of its excellent illustrations. The second edition has even more and equally good illustrations. The arrangement of the various main subjects has been changed somewhat and new material has been added. Most

of the references are at the end of the sections to which they refer. Summaries, problems, and a glossary should make it a useful high school text. There is a good index.



LIFE-GIVING LIGHT. *A Century of Progress Series.*

By Charles Sheard. *The Williams & Wilkins Co., Baltimore.* \$1.00. 5 x 7½; x + 174; 1933.

Sheard's book is plentifully studded with quotations from scientific textbooks, classical literature, and the Bible, and its style frequently rises to such heights as, "Man, a creature of heaven-given light, has supplemented Nature by first imitating her and then, having wrested some of her secrets from her, by challenging her." With the aid of this little book the whole subject of the biological effects of light can be made plain to any clergyman.



BÉCHAMP OR PASTEUR? *A Lost Chapter in the History of Biology.*

By E. Douglas Hume. *Founded upon MS. by Montague R. Levenson. C. W. Daniel Co., London.* 6 shillings. 5¼ x 8; 301; 1932.

This is the second edition of a bit of anti-vivisection and anti-vaccination propaganda intended to prove that Pasteur's conclusions are false and that one of his opponents, Béchamp, ought to be regarded as a hero by all health faddists. Maybe he should.



THE LIVING UNIVERSE.

By Sir Francis Younghusband. *E. P. Dutton and Co., New York.* \$3.00. 5¾ x 8½; x + 252; 1933.

In this book the author develops further his interpretation of the universe as the manifestation of a Cosmic Spirit and his speculations as to the existence of life on the planets of other stars.

BULLETIN DE L'ASSOCIATION DES DIPLÔMÉS DE MICROBIOLOGIE DE LA FACULTÉ DE PHARMACIE DE NANCY, No. 6.

Faculté de Pharmacie, Nancy. 6¼ x 9½; 48; 1933 (paper).



HUMAN BIOLOGY

JOCASTA'S CRIME. *An Anthropological Study.*

By Lord Raglan. *E. P. Dutton and Co., New York.* \$2.25. 4½ x 7¼; xii + 215; no date.

Few acts are surrounded with such an aura of horror as incest, yet we should be hard put to explain why intercourse between near kin should arouse a reaction of horror. Nor have moralists or anthropologists been more successful in their attempted explanation of the incest taboo. Some have postulated an instinctive basis; but an instinct which somehow got left out of the composition of the ancient Egyptians, Persians and Incas is hard to credit. Some have derived the incest taboo from observation of the harmful effects of inbreeding; but there is no good evidence that inbreeding is harmful and, as Lord Raglan points out, primitive man was not a legislator who established new customs to serve certain rational ends.

Lord Raglan himself suggests that the origin, not only of the incest taboo, but of the taboos on menstruous women and on a man's meeting his mother-in-law, is to be found in magic. The second of these taboos is probably the oldest.

We may perhaps suppose that the mysterious and apparently causeless character of the [menstrual] flow filled early man with a surprise which developed gradually into alarm, and later into horror, and that he developed *pari passu* a most elaborate system of precautions against the magical dangers which he believed to threaten him.

Since running water is a sovereign antidote against magic, the safest plan was for the men of a tribe to live on the opposite side of a stream from the women and merely visit them surreptitiously for intercourse.

This would not last for very long; old men would stay with the women, and old women with the men, and the idea might gradually arise that it was safe for people of both sexes to live on the same side so long as they did not have sexual intercourse. There was as yet no individual marriage—the divine king and queen

were the first pair to be married—but the men would tend to visit the same women, those nearest to them on the opposite bank, and these would often be in fact their cross-cousins, though the relationship was not yet recognized: when individual marriage came into existence, cross-cousins were the people between whom it could be most easily arranged, if the rule of exogamy was to be observed.

All this time, we may suppose, the belief in ancestral spirits had been slowly developing, and the danger from a breach of the menstrual taboo, which had formerly been supposed to come from the women themselves, or their blood, was in part transferred to the spirits, who thus became jealous guardians of the taboo. The women were secluded during their period, and old women were set to guard them. . . . Eventually, when individual marriage was evolved, the individual mother-in-law replaced the old women of the group.

In this way would come about the organization of the tribe into exogamous clans, the members of which would be forbidden to have intercourse with each other, however remote their relationship might be, while near relatives might have intercourse if they belonged to different clans. In a later stage of development the clan system broke down and the taboo on intercourse was applied to near relatives on both the father's and mother's side.

There are, however, also traces of another magical system, a creation ritual in which a brother married his sister. The myth of Oedipus and Jocasta is, according to the author, a reminiscence of the conflict between these two incompatible systems of magic, one commanding a man to marry his sister, the other forbidding him to do so.

This is an extremely interesting book on a puzzling subject. The author does not claim to have proved his theory; it has, however, the advantage over previous theories that it attempts to account for all the features of the three early sexual taboos and not merely a few selected features of one selected taboo. The author has been so thoughtful as to provide the reader with a bibliography of six pages and an excellent index.



POPULATION TRENDS IN THE UNITED STATES.

By Warren S. Thompson and P. K. Whelpshon. McGraw-Hill Book Co., New York.

\$4.00. 5½ x 9; x + 415; 1933.

When Mr. Hoover's Research Committee

on Social Trends was preparing its report, it was found that the results obtained in a number of the investigations required more extended treatment than could be given in the report itself. In addition, therefore, to the summaries of these subjects in the report separate monographs are published giving the detailed evidence and discussion. In this monograph the authors deal with the growth and distribution of population in the United States, the national origins of the white population, age and sex composition, marital condition, birth and death rates, population growth from immigration and natural increase, probable trends and consequences of future growth, and population policy. Since 1920 the growth of most agricultural states has been slow as compared with earlier decades. In metropolitan districts the growth of the suburbs has been much more rapid from 1920 to 1930 than that of the central cities. The forces affecting the growth of particular localities and the probable effects of national planning are discussed.

In administering the quota provisions of the immigration laws it was necessary to estimate the national origins of the white population in 1920. According to the estimates of the committee 41.4 per cent was of British and North Irish origin, 16.3 per cent German, 11.2 per cent South Irish, 4.3 per cent Scandinavian, 5.8 per cent from other countries of northwestern Europe, and 4.3 per cent Canadian. Thus about 83 per cent of the white population had its origin in northwest Europe or Canada. The high birth rates of the newer immigrants rapidly decline, while the rural population, which is of predominantly northwestern European origin, has a higher birth rate than the urban. It is therefore probable that the composition of the population will not change materially. However, the authors see no eugenic basis for the present quotas and suggest that it may be desirable "to encourage a moderate number of superior persons having the background of other cultures to migrate hither, to the end that our social order may keep itself fluid and adaptable."

On the basis of extrapolated trends in birth rates, death rates and immigration, the authors derive various estimates of the

future growth of the population of the United States. According to the highest of these the population will exceed 200,000,000 in 1980 with no indication of growth ceasing for several decades thereafter; according to the lowest it will increase to about 136,000,000 in 1955 and then decrease to about 126,000,000 in 1980; according to the trends which the authors consider most probable the population in 1980 will be almost at its maximum size with about 155,000,000 persons.

The final chapter deals with the change from the former encouragement of immigration and fecundity to the present restriction of immigration and largely unintentional but nevertheless effective handicaps on the production of large families. If an increase of the birth rate is felt to be desirable, the authors suggest mothers' wages as a means of encouraging it. As to the program of the eugenists, they point out some of the difficulties of agreement as to who are "desirable" and "undesirable." Besides the numerous tables in the text there is a tabular appendix of 70 pages and an index.



AMERICAN WINES and How to Make Them.

By Philip M. Wagner. Alfred A. Knopf, New York. \$2.00. $5\frac{1}{4} \times 7\frac{1}{2}$; xix + 295; 1933.

Mr. Wagner started out to be a crusader, aiming to lead his people out of arid America into a promised land flowing with good wine grown if not in the back-yard at least on the nearby farms of the land of the free. But fate, this time in the persons of an oddly assorted pair, Capt. W. H. Stayton and Franklin D. Roosevelt, played this gallant young knight a dirty trick. Repeal beat him to it, as the phrase goes. Wine flows in this so lately dry land, right enough. But even now only an infinitesimal fraction of it is home-made wine, and in six months still less of it will be. In short, we greatly fear that noble as was Mr. Wagner's intent the fact is that no sensible man who has anything else to do is going to make wine at home when he can buy a good product at a moderate to low price. The reason is simple, and is really better and more clearly stated in this

excellent book than anywhere else we can recall. It is that to make a really good wine requires a lot of care, thought, intelligence, labor, and trouble. To make a distinguished wine requires in addition God's active coöperation, and experience shows that this coöperation, in the matter of wine making as well as others that might be mentioned, is distributed with a certain discrimination. To be sure our author urges that it is *not* much trouble to make good wine at home. But what constitutes "much trouble" is plainly a relative matter. If you can only buy good wine surreptitiously, uncertainly, and at relatively great cost, then the trouble required to make it is worth taking. But if, on the other hand, you can buy it from the chain store around the corner at less than a dollar a bottle the case becomes distinctly otherwise.

It pains us uncommonly to take so realistic an attitude, because Mr. Wagner has put an enormous amount of research into the writing of this book, and altogether has done a fine piece of work. It is just too bad that it will not have the influence that it would have had if Bishop Cannon had continued to rule the land.



THE PENINSULA OF YUCATAN: Medical, Biological, Meteorological and Sociological Studies. Carnegie Institution of Washington Publication No. 431.

By George C. Shattuck. In collaboration with the following authors: Joseph C. Bequaert, Francis G. Benedict, William J. Clench, Frank H. Connell, Kenneth Goodner, Margaret M. Hilferty, Helen C. Maher, Katheryn McKay, John L. Page, Robert Redfield, Oliver Ricketson, Jr., Jack H. Sandground, George M. Saunders. Carnegie Institution of Washington. \$8.00 (paper); \$9.00 (cloth). 9×12 ; xvii + 576 + 68 plates + 2 folding maps; 1933.

Thirteen collaborators assisted the author in producing this interesting and useful volume. The three expeditions, organized by the Department of Tropical Medicine of Harvard University under the auspices of the Carnegie Institution of Washington, were made in 1929, 1930 and 1931. The first part of the volume (chap-

ters I-V inclusive) deals with general and miscellaneous information about Yucatan. This part will be most useful to those wishing to visit Yucatan either for purposes of investigation or for travel. In part II (chapters VI-XXI inclusive) will be found reports of medical surveys and other data. Much detailed information is given also concerning local living conditions in Guatemala and British Honduras and among the Mayas of Chiapas. There are sections on bacteriological and serological studies; certain helminthic and protozoan parasites of man and animals; tests on basal metabolism, Kahn tests and blood counts; syphilis and other diseases; vital statistics and meteorological studies. In the concluding chapter of part II is given a general survey of the more important facts brought out by the data presented, a discussion of the opportunity for further studies of disease and the necessity for prolonged and coordinated investigations of the problems involved in the adjustment of various races to tropical climates. Part III (chapters XXII-XXVI inclusive) deals with the surveys in 1931 which were concerned chiefly with malaria and amoebiasis. Data are presented also on observations in blood-pressure, blood studies and other clinical material.

The fourth and last part (chapters XXVII-XXIX inclusive) is concerned with the natural history of the region of Chichen Itza. The volume is well documented and is abundantly illustrated with excellent plates, maps and drawings. There is no index, an inexcusable omission in such a work.



PROMINENT DANISH SCIENTISTS Through the Ages. With Facsimiles from Their Works.

By V. Meisen, Editor. Levin and Munksgaard, Copenhagen. 9 Dan. Cr. $7\frac{3}{4} \times 11$; 195; 1932 (paper).

This is an entertaining book. Issued in commemoration of the 450th anniversary of the University Library of Copenhagen it gives a condensed survey of the achievements of Danish men of science in those studies which the library is particularly intended to serve: namely, natural science,

mathematics and medicine. The forty-five men in review (none is now living) were selected on the basis of their original discoveries or theories of far reaching significance. One of the most fascinating features of the book is the reproduction, in facsimile, in each essay, of characteristic fragments of the man's work. Unfortunately no portraits are given. Among the first of those listed are Henrik Harpestraeng (d. 1244) the earliest Danish medical author whose most famous writings were on herbs. Then comes Petrus de Dacia (1300) renowned for his calendar and astronomical tables. From the middle of the seventeenth century beginning with the two Bartholins, Thomas (d. 1680), anatomist, and Erasmus (d. 1698) physicist, Oluf Borch (d. 1690) chemist and botanist and Nicolaus Steno (d. 1686), one of the greatest Danish naturalists, the number of investigators increases much more rapidly. Considerably later comes Otto Fabricius who when a young man went to Greenland (1768-73) as a missionary. His *Fauna of Greenland*, written in Latin, describes 473 animals, 130 of which were new to science. Johann C. Fabricius, who did his pioneering work in insects, was of the same period.

Classifying these famous men by professions we find 7 anatomists and physiologists, 6 botanists, 11 zoologists and biologists, 18 physicians, 4 geologists and paleontologists, 14 chemists, 4 physicists, 3 mathematicians, and 3 astronomers. The volume is indexed.



OUT OF MY LIFE AND THOUGHT. An Autobiography.

By Albert Schweitzer. Translated by C. T. Campion. Henry Holt and Co., New York. \$2.50. $5\frac{3}{8} \times 8\frac{1}{4}$; 288; 1933.

Dr. Albert Schweitzer is one of the most amazing and romantic figures of the modern world. Born an Alsatian he became in turn, but without relinquishing activity in the old fields as he took on new ones, a university teacher and researcher in philosophy, a great organist, one of the world's leading authorities on Bach and his music, and a medical missionary in Equatorial Africa. All of this has been packed into the 58 years since he was born. In an

earlier number of this REVIEW (Vol. VII, pp. 227-8) there appeared a notice of his *On the Edge of the Primeval Forest*, a most interesting and stimulating account of his medical work in Africa.

The present book tells as much of his whole life story as he is apparently willing to put on paper. Those readers who are not deeply religious, as he is, will regret that it is obviously his nature to speak much more freely and fully about his inner spiritual life than about his material doings. He is plainly a vigorous, motor, cyclothymic personality type, and has had an extraordinary range of interesting experiences. But he tends to be reticent about them, and particularly so at crucially interesting points. On the other hand, he expounds his theological, ethical and religious ideas at great length. However, in spite of this defect, if it is a defect, this is a notable autobiography. We recommend it to our readers.



AMERICAN AGRICULTURAL VILLAGES: 1930. *An Analysis of Census Data. American Statistical Association Monograph No. 1.*

By Irving Lorge under the direction of Edmund deS. Brunner. *American Statistical Assoc.*, New York. \$1.00. 6 x 9½; iii + 133; 1933 (paper).

This is a continuation for the Census of 1930 of the work of Fry in *A Census Analysis of American Agricultural Villages* for the Census of 1920. It deals with the same 177 villages, for each of which is given the population growth or decline from 1920 to 1930, as well as population by color, nativity and parentage, native whites born in or outside of state of residence, place of birth and year of immigration of foreign-born, age distribution by sex, marital condition by sex, school attendance by sex and age, illiteracy by sex, color and nativity, naturalization of foreign-born whites, home ownership, size of family, gainfully employed persons by sex and age, occupations, and marital condition of gainfully employed females. Totals are also presented for the Middle Atlantic states, the South, the Middle West, the Far West and the United States. The interpretation

of the tables is part of a report of President Hoover's Research Committee on Social Trends. It is, however, noted that

In 1930 agricultural villagers represent an older population, a larger proportion of which is married. The population is more literate and attends school to a considerably greater degree than was the case in 1920. Occupationally, they find principal employment in four major industry categories. Manufacturing, trade or merchandising, agriculture and transportation, in that order. Of these, merchandising made the largest proportional gain. There are fewer very young and very old males gainfully employed. In general, however, there has been a consistent increase in the number of gainfully employed females except in the early age brackets.



TO BE OR NOT TO BE. *A Study of Suicide.*

By Louis I. Dublin and Bessie Bunzel. *Harrison Smith and Robert Haas, New York.*

\$3.50. 5¼ x 8½; x + 443; 1933.

In this interesting study Dr. Dublin deals with suicide in its statistical, ethnological and psychiatric aspects. For his statistical treatment he draws not only from the official publications of various countries but also from the records of the Metropolitan Life Insurance Company. The differing tendency towards suicide in different races is, he concludes, the result of social rather than of biological heritage. There is a correlation of $-.47 \pm .05$ between the business index and the suicide rate corrected for trend and seasonal variation in ten large American cities from 1910 to 1931. The lower suicide rates in Catholic countries, in rural areas and among married persons he attributes to the greater social integration of these groups.

In his ethnological section Dublin shows that the horror of suicide characteristic of the Hebrew and Christian tradition is by no means universal. Among some primitive peoples suicide is unknown, while in others it is quite prevalent. The religions of the Far East in general approve of it, and it is even institutionalized in the customs of suttee and hara-kiri. The Greeks and Romans took a much more lenient view of suicide than do most modern moralists. Nor was it until the time of Augustine that the Christian church regarded it as a crime under all circumstances.

In his psychiatric section Dublin shows

the value of psychoanalysis in understanding the motives behind suicide—emotions of fear, inferiority, hatred and guilt—and the influence of mental disease on the act. He also considers methods which have been tried for preventing suicide and the broader movement towards sound mental health for the population as a whole. There is an appendix of statistical data, a bibliography of 14 pages and an index.



EMPLOYED BOYS AND GIRLS IN ROCHESTER AND UTICA, NEW YORK. *United States Department of Labor, Children's Bureau Publication No. 218.*

By Alice Channing. U. S. Government Printing Office, Washington. 10 cents. $5\frac{7}{8} \times 9\frac{1}{2}$; v + 74; 1933 (paper).

Serious students of sociology have long held the theory that children who are either too dumb to learn, or whose parents cannot afford to permit the continuance of their education, or who for other reasons are fed up on schooling, tend to leave school and go to work as soon as it is legally possible to do so. This treatise proves that this theory was correct so far as concerned Rochester and Utica, N. Y., in the late spring of 1927. The proof is thorough, precise, documented, and detailed. For ourselves we shall never doubt the theory again, at least so far as concerns Rochester and Utica, although (*vide* Table 2, p. 5) there was one employed girl in Utica whose age was not ascertained at the time of the study. The report is packed with information of thrilling interest, novelty, and importance. For example it is shown by the data of Table 13 (p. 45) (in more detail than we can spare space for here) that the median cash wage of 16 year old boys who had been employed one year or more was higher by \$2 per week than that of 16 year old boys who had been employed less than one year. To give another example, from the many presented: careful analysis of the intelligence tests demonstrated that the higher the boys' I.Q.s the less often were they out of a job. Who, we ask you, would ever have supposed *that* to be true? The same relationship, we are shocked to report, was found *not* to hold for the

girls. [Reginald the Office Boy, whose worldly wisdom is becoming appalling, says that he knows why.]

We regret that lack of space forbids any more extended review of this profound and thorough piece of research.



A GERMAN DOCTOR AT THE FRONT. (*Die Front der Ärzte.*)

By Wilhelm His. Translated from the Original German by Gustavus M. Blech and Jefferson R. Kean. National Service Publishing Co., Washington. \$2.50. $5\frac{7}{8} \times 9$; viii + 230; 1933.

The discoverer of "the bundle of His" and the son of the renowned anatomist, also named Wilhelm, records here his experiences in the Great War during which he held one of the highest medical positions among the Germans, taking him into the various theaters of the war on both eastern and western fronts. He describes what he has seen simply and dispassionately, uncolored by any sentiment of his own. The Great War he regards not as the greatest catastrophe in the history of mankind, as some assert, but rather as the greatest of human experiences. The medical lessons which the war gave in the care and restoration of the injured, in the shelter, feeding, moving and care of masses under primitive conditions, that is, the control of epidemics, he thinks will last. The progress of medical science between 1850-1920 is portrayed in the table (p. 228) giving the ratio of killed to died from disease:

In the war in the Crimea 1854-56 (English).....	1 to 3.6
In the Italian war 1859.....	1 to 3.3
In the Austro-Prussian war 1866 (Prussians).....	1 to 1.3
In the Franco-Prussian war 1870-71.....	1 to 0.53
In the World War (Germans)....	1 to 0.1

The book should be of interest to military medical men and physicians and surgeons, and possibly also to the general reader who may enjoy the descriptions of the various countries and their populations, and frequently interspersed sidelights of human contacts which relieve an otherwise dark background.

THE BARBARY COAST. *An Informal History of the San Francisco Underworld.*

By Herbert Asbury. Alfred A. Knopf, New York. \$3.00. 5 $\frac{1}{2}$ x 8 $\frac{1}{2}$; 319 + xi; 1933. This history of low life in San Francisco is detailed, realistic and meticulously documented. The life stories of such colorful ladies as the Galloping Cow, who tended bar in her own saloon and once broke a man's back because he had ventured to chuck her under the chin, and Tessie Wall, who drank twenty-two bottles of wine "without once leaving the table" at her first dinner with the man she subsequently married, and still more subsequently shot, are told in all simplicity and candor. Tessie, by the way, only retired from business in the year 1918 or thereabouts. And this fact is of significance in the appraisal of the whole story which Mr. Asbury sets forth with such great skill and erudition. It is not ancient history, not something comparable to the doings of the Caesars as recorded by Suetonius, but an account of the goings-on in this country within the life time of probably a majority of the readers of this REVIEW. As we have had occasion to remark before, man is an oddly curious animal.

The book is abundantly and entertainingly illustrated, has a bibliography and an excellent index.



AN INTRODUCTION TO THE SOCIOLOGY OF ISLAM. *In Two Volumes.*

By Reuben Levy. Williams and Norgate, London. £1.1.0 per volume. Vol. I. 5 $\frac{3}{8}$ x 8 $\frac{5}{8}$; viii + 410; 1931. Vol. II: 5 $\frac{3}{8}$ x 8 $\frac{5}{8}$; v + 426; 1933.

Although the author covers a wide field in these two volumes—grades of society, status of women and children, jurisprudence, Caliphate and central government in Islam in the first volume, and religious conceptions, moral sentiments, usage, custom and secular law, government in the provinces, military organization and science in the second—he has succeeded in giving an extremely lucid account of a system of religion and government which not only has been of great importance in the history and politics of the past in the East,

but still is at the present time. The author considers the theories of the classical period of Islam, but also makes an attempt "to discover how far the people who have accepted Mohammedanism are content to be guided by them;" how they have adapted the laws as embodied in the Koran according to local custom or tribal law, and how religious difficulties have been overcome with the introduction of a Western system of popular government in Turkey. Like most peoples the followers of Islam have evolved ways of "getting around the law."

Besides numerous annotations, each chapter is equipped with a bibliography, and each volume its own index. A thoroughly scholarly and important treatise.



HEART BURIAL.

By Charles A. Bradford. George Allen and Unwin, London. 8s. 6d. net. 5 $\frac{1}{4}$ x 7 $\frac{1}{2}$; 256; 1933.

It is the author's opinion that heart burial "was but an offshoot of the practise of evisceration at death which had been in vogue from the later Stone Age." It appears that the desire to check bodily decay led to the separate disposal of the viscera wherever the custom of embalming was in use, though in Egypt it was eventually done with special pomp and ceremony. In occidental Europe the first authentic record is that of the separate burial of the heart of D'Arbrissel, founder of the order of Fontevault, in 1117 A.D. The author agrees in the opinion that it was due to "feminine tenderness tinged with religion."

Since the twelfth century, in the area that is now the London Postal Area there have been recorded 108 cases of separate burial of the viscera at death. Of these "some 55" are authentic cases of heart burial. The first mentioned is that of King Henry II in 1189, and the last that of Thomas Hardy in 1928. The cases are listed chronologically and alphabetically but no attempt is made to give a reason why in these particular cases it should have been done.

ERINNERUNGEN, *Bekenntnisse und Betrachtungen*.

By Gottlieb Haberlandt. Julius Springer, Berlin. 9.60 RM (paper); 10.80 RM (cloth). $5\frac{1}{2} \times 8\frac{1}{2}$; vii + 243, 1933.

Two features of this autobiography of the author of *Eine Botanische Tropenreise* and *Physiological Plant Anatomy* deserve mention here. One of them is the air of *Gemütlichkeit* that pervades the book and which only partly comes from the anecdotes that turn up every few pages. Haberlandt writes more about his teachers and colleagues and the universities in which they worked than he does about himself. During his student days at Vienna and at Tübingen and during the rest of his career at Graz and Berlin he worked with the men who helped to make German universities the powerful influences they were, and his notes on the men and the period are valuable in themselves. The other characteristic of the book is his effort to account for the influences of family life and education that turned him toward a scientific career and to outline the train of thought that led him from one scientific problem to another. Haberlandt is an interesting man and his own interests and accomplishments are not confined to academic subjects.



APPLIED EUGENICS.

By Paul Popenoe and Roswell H. Johnson. The Macmillan Co., New York. \$2.60. $5\frac{1}{8} \times 7\frac{3}{4}$; ix + 429; 1933.

The authors here present a revised and augmented edition of this standard work on eugenics which was first published in 1918. Its principal object is to propagate the tenets of orthodox eugenics and the authors employ their wide knowledge of biology and sociology in the attempt to give a scientific basis to these doctrines.

The mechanism of inheritance and the importance of the hereditary factors are well summarized in the light of modern genetics. They emphasize the burden placed on society by the inferior individuals and so demonstrate the need to eliminate these and increase the number of those of superior caliber. The measures proposed in order to achieve this are well known: segregation and sterilization of

the feeble-minded, more stringent marriage laws, inducement, financial or otherwise, to superior individuals that they marry earlier and reproduce more, etc. All this, they foresee, will ameliorate the society of the future because, "the best then will be better than the best now and the worst then be better than the worst now."

The philosophy underlying this work may or may not be acceptable to the reader, but notwithstanding, this book remains valuable as a source of literature for the student in the field of human biology.



THE PUBLIC DOMAIN OF NEVADA AND FACTORS AFFECTING ITS USE. U. S. Department of Agriculture Technical Bulletin No. 301.

By E. O. Wooton. U. S. Government Printing Office, Washington. 75 cents. $5\frac{7}{8} \times 9\frac{1}{8}$; 52 + 2 folding maps; 1933 (paper). The necessity of some legislative action to regulate the use or disposal of the public domain has been and is continually urged. In those states where these lands are extensive it becomes a complex economic problem. Especially is it so in Nevada where they constitute about 95 per cent of the area of the state and the whole agricultural organization is here dependent upon their use, present and future.

This problem the author investigates with regard to the type of legislation that would be introduced with greatest benefit to all. He finds that the physical peculiarities of the different regions of Nevada added to the desire of the established stockmen to maintain the *status quo*, or at least lose nothing by a change, complicate the question in this state more than elsewhere. With all those who have written on the subject he advocates that something be done about it, but, confronted by the above difficulties, proposes that a more intensive study be undertaken before an attempt is made to enact laws.



MEXICO BEFORE CORTES. *An Account of the Daily Life, Religion, and Ritual of the Aztecs and Kindred Peoples.*

By J. Eric Thompson. Charles Scribner's

Sons, New York. \$2.50. $5\frac{1}{2} \times 8$; x + 298; 1933.

The layman who reads this book will be amazed at the extent of information concerning the racial cultures of early Mexico which diligent research has uncovered. The author, in charge of Central and South American archaeology at the Field Museum of Chicago, has written an authoritative and highly readable account of the daily life, religion and ritual of the people who inhabited the Valley of Mexico and adjacent regions before the time of Cortez. The volume is to a certain extent complementary to T. A. Joyce's *Mexican Archeology*. Training of children was very strict. Separate colleges existed for educating the sons of the middle classes and of the nobility but both types of school were attached to religious temples so that the training could be closely supervised by the priests. The habit of lying had little hold on these peoples, not because they were inherently honest, but because of the severity of the punishment meted out to the offender, particularly to the young. The account is an amazing record of a people, primitive yet civilized, intensely superstitious, highly skilled in artistry and possessing a remarkable code of ethics. The volume is interestingly illustrated and is indexed.



THE POPULATION OF ATHENS IN THE FIFTH AND FOURTH CENTURIES B.C.

By A. W. Gomme. Basil Blackwell, Oxford. 5 shillings net. $5\frac{3}{8} \times 8\frac{1}{2}$; vii + 87 + folding map; 1933.

On the basis of statements of army strength in Thucydides and other historians, of numbers of recruits in inscriptions, of definite but not always trustworthy statements about the total adult male population, and, as a check, of the production and importation of grain, the author makes a rough estimate of 315,500 for the total population of Attica in 431 B.C., which was reduced by the plague to 218,000 in 425 and again rose to 258,000 by 323. Between 480 and 431 there had apparently been a considerable natural increase in the population. The number of slaves, he concludes, was at no time larger than 100,000

to 120,000. He also finds no reason to suppose that the exposure of children was a regular practice. The evidence for this, he points out, is mostly drawn from the romantic plots of tragedies and comedies and "the motive is never economic, but a warning oracle from on high, or because the child is illegitimate—a reason which has caused infanticide or exposure in all times and countries."



GREAT MEN OF SCIENCE. *A History of Scientific Progress.*

By Philipp Lenard. Translated from the Second German Edition by H. Stafford Hatfield. The Macmillan Co., New York. \$3.00. $5\frac{3}{4} \times 8\frac{1}{2}$; xx + 389; 1933.

This is a useful book to have available, particularly for graduate students in the sciences, and also, to speak euphemistically, to enable their professors to "refresh their memories" about the lives and doings of their intellectual forbears. It is composed of brief, but adequate, accounts of the lives, principal achievements, and significance of over 60 of the great figures in the history of science, beginning with Pythagoras of Samos and ending with Friedrich Hasenöhl. The author is a Nobel laureate in physics, and it is therefore natural that the men treated are preponderantly from the physical and mathematical sides. Indeed Charles Darwin and Linnaeus are the only primarily biological persons who get a separate (shared) chapter. In this chapter, however, is included some account of another biologist called, oddly to our eyes, Johann Mendel.

The treatment throughout is highly intelligent, readable and critical. The book is an important addition to the reading literature of scientific history. It has name and subject indices.



DIE BEHAARUNG DES MENSCHEN. *Eine sexual- und konstitutionswissenschaftliche Abhandlung. Monographien zur Frauenkunde und Konstitutionsforschung Nr. 17.*

By Oskar F. Scheuer. Curt Kabitzsch, Leipzig. 6 marks. $6\frac{1}{4} \times 9\frac{5}{8}$; ii + 93; 1933 (paper).

Within 87 pages, the author covers the subject of human hair. He goes all the way from the scent of hair to the bearded ladies of the side-shows. Man's relation to other mammals in respect to hair, racial differences in hair, baldness, physiological functions of hair, head hair, pubic hair, axillary hair, beards in male and female, extent and distribution of hair in the two sexes,—all these and many more aspects are discussed. Nearly 4 pages are devoted to Darwin's theory of the sexual selection of hair and the various opinions advanced since to replace it.

The paper is a collection of the opinions and observations of a good many different investigators and writers. There are 17 illustrations, many of them—such as the picture of Zenora Pastrana, the bearded lady—being the same ones that usually appear in treatises on hair. The bibliography includes 175 titles, nearly all of which are German.



THE LAND OF FEAST AND FAMINE.

By Helge Ingstad. Translated from the Norwegian for the first time by Eugene Gay-Tiffé. Alfred A. Knopf, New York. \$3.50. 5 $\frac{1}{8}$ x 8 $\frac{1}{2}$; [11] + 332; 1933.

An interesting account of life in the Barren Lands of Canada by a Norwegian attorney, who tired of the placid life of the law and became a hunter and trapper. It contains a wealth of shrewd observations on the Indians of the far North, and on the habits of the game and furbearing animals. And the story has plenty of thrills. The author lived off the country and had no resources other than his own to fall back on. About the only thing in the whole book (which contains some tall tales) that at first stirred a certain low scepticism within us was the alleged scorn with which he successfully rebuffed the amorous advances of the ladies of those sparsely settled parts. But in the end we concluded that this was probably all right; the ladies in question appear to have been long on dirt and short on pulchritude. The book contains some excellent photographs, taken by the author. There is no index.

LIFE OF CHRISTIAN SAMUEL HAHNEMANN. *Founder of Homœopathy.*

By Rosa W. Hobhouse. C. W. Daniel Co., London. 7s. 6 d. net. 5 $\frac{1}{4}$ x 8; 288; 1933.

Although exhaustive treatises on the life and work of Hahnemann are well known to the professional medical historian and brief biographical sketches of this great pioneer are readily accessible in the shorter medical histories, no easily available short survey of Hahnemann's life and contributions to medicine has been provided for the casually interested student of medical history. Mrs. Hobhouse, with a fine insight into the kind of biography that would supply this need, has presented in this inexpensive little book an interesting and well written account of the life of this extraordinary doctor. A short list of Hahnemann's most important writings, a list of books about Hahnemann, and an adequate index are included.



RACES AND ETHNIC GROUPS IN AMERICAN LIFE.

By T. J. Wooster, Jr. McGraw-Hill Book Co., New York. \$2.50. 5 $\frac{1}{8}$ x 9; xii + 247; 1933.

This is one of a series of monographs published under the direction of President Hoover's Research Committee on Social Trends. The author's object is to describe briefly the changes that have occurred in the racial composition of the United States and the social problems that have arisen as a consequence.

The various topics are, after a brief survey of immigration: the racial differences in movement and distribution, urban occupation, education, crime and assimilation. It is demonstrated that racial assimilation by intermarriage is exceedingly slow and with regard to the Negro legally impossible; so the author concludes that we must strive at least for cultural assimilation to eliminate interracial difficulties. This can be achieved only by real cooperation and mutual understanding between the members of the different ethnic groups.

It is evident that this book is not intended to be an original contribution but rather an outline of the findings of the

more recent investigators in the field. The author's extensive knowledge of the Negro leads him to devote most of this volume to the problems of this race, undue importance without doubt. An apparent oversight is the gross error on page 151 where cancer of the heart is mentioned. Probably cancer of the breast was intended.



HEALTH AND ENVIRONMENT.

By Edgar Sydenstricker. McGraw-Hill Book Co., New York. \$2.50. $5\frac{7}{8}$ x 9; xii + 217; 1933.

This is perhaps the outstanding monograph in the series of studies on Social Trends prepared for Mr. Hoover. Mr. Sydenstricker has not only put his material in such shape that it is readily comprehended by the general reader, but he has also done one of the most sagacious, scholarly, and thorough pieces of work in general biostatistics of this century. The special worker in this field will find it very valuable as a reference book. The author states in the preface that

the factual material on the relation of environment to health is lopsided. On some phases great masses of data are available; on others the data either are wholly lacking or are pitifully few. Most of the material is indirect in its bearing upon the subject. is not sufficiently specific, and is discouragingly inconclusive. Yet a general view of it is worth while, and that is all this monograph pretends to offer.

The investigation has been limited to a review of the "more important evidence bearing upon environment and health, without, however, losing sight of the established laws of heredity." The data upon which the study is based are arranged in 54 tables. Numerous figures also exhibit the graphical arrangement of the data. The book is thoroughly documented and indexed.



LE TRAVAIL HUMAIN. *Revue Trimestrielle*. 1^{re} Année—No. 1.

Conservatoire National des Arts et Métiers, 292 Rue Saint-Martin, Paris. Subscription price: 100 francs (France and Colonies); 130 francs (foreign).

This new journal, edited by MM. J. -M. Lahy (*Directeur d'études à l'École des Hautes Études et à l'Institut de Psychologie de l'Université de Paris*) and H. Laugier (*Professeur à la Sorbonne et au Conservatoire National des Arts et Métiers, Paris*) expresses well its objectives in its potential sub-title, "Knowledge of man from the point of view of the judicious utilisation of his activities." It will be useful for all students of human biology, and thoughtful industrialists and other employers of labor as well. The position and repute of its editors will ensure the maintenance of high scientific standards. We wish this new venture all success and take great pleasure in recommending it to our readers.



A BIBLIOGRAPHY OF DIFFERENTIAL FERTILITY. In English, French and German.

Edited by Eldon Moore on behalf of Commission II of the International Union for the Scientific Investigation of Population Problems. International Union for the Scientific Investigation of Population Problems, Kensington Gore, London, S.W. 7. 2 shillings. $9\frac{3}{4}$ x 6; vi + 97; 1933.

This bibliography is a useful and welcome fruit of the work of the Commission on Differential Fertility, Fecundity, and Sterility of the International Union for the Scientific Investigation of Population Problems. It includes over 1,100 references—about 200 each in French and German and over 700 in English—arranged in chronological order. The English references range from Malthus' *Essay on the Principle of Population* in 1798 to 1931, the French—largely works published in Belgium—from 1838 to 1929, and the German from 1919 to 1930. Regular official publications are given in an appendix. The usefulness of the bibliography is enhanced by an index of authors.



THE WORLD SINCE 1914.

By Walter C. Langsam. The Macmillan Co., New York. \$4.00. $5\frac{1}{2}$ x $8\frac{1}{2}$; xv + 723; 1933.

THE WORLD SINCE 1914. *Second Edition with Supplementary Chapter.*

By *Walter C. Langsam*. *The Macmillan Co., New York*. \$4.00. $5\frac{3}{4} \times 8\frac{1}{2}$; xv + 742; 1933.

If you have forgotten or never knew the intricate pattern of events that led up to the World War, read this book. When you have read it, you will be less addicted to talking glibly about "war guilt" than perhaps you were before. Besides the excellent account of the origins and course of the war and of the "Peace to end peace" the book gives concise and complete political and economic histories of the various nations in the post-war period. It also contains a number of maps and illustrations, a voluminous bibliography of 33 pages and an index.



THE BUILDERS OF STONEHENGE. *Evergreen Essays No. 10*.

By *Rendel Harris*. *W. Heffer and Sons, Cambridge, England*. 3s. net. $6\frac{1}{2} \times 8\frac{1}{4}$; 73; 1932 (paper).

The author derives many English place names, especially near Stonehenge, from Egyptian originals and identifies various Cornish saints with Osiris masquerading in Christian vestments. On this basis he concludes that the Egyptians built Stonehenge for the joint worship of Rā and Osiris. It is true that both Stonehenge and the Egyptian temples are megalithic; yet if there had been such extensive Egyptian colonization in Britain as Mr. Harris postulates, sculptures or other artefacts of unmistakably Egyptian origin would surely have been discovered.



FLYNN OF THE INLAND. *Eighth Edition*.

By *Ion L. Idriess*. *Angus and Robertson, Sydney*. 6 shillings. $4\frac{3}{4} \times 7\frac{1}{4}$; xiv + 306; 1933.

In both style and context this book is about like every other account of the work of medical missionaries with this exception: there is less emphasis than usual on the beneficence of God and a great deal more on the wisdom of man in designing automobiles, airplanes, and radio sets. The scene is the interior of Australia, an almost barren country sparsely settled by white

men, and the theme is the persistent effort of John Flynn to better the means of transportation and communication for himself and his co-workers. There is little of special interest to biologists or anthropologists.



RASSENKUNDE UND RASSENGESCHICHTE DER MENSCHHEIT. *Fünfte Lieferung (Bogen 37-46)*. *Sechste Lieferung (Bogen 47-59 u. Titelfolien)*.

By *Egon F. von Eickstedt*. *Ferdinand Enke, Stuttgart*. Lief. 5, 11 marks; Lief. 6, 13 marks. $7\frac{1}{8} \times 10\frac{3}{8}$; Lief. 5, 160; Lief. 6, viii + 200 + folding map, 1933 (paper).

Previous numbers of this series have been noticed in the last two numbers of this REVIEW. By concluding the study of the negro populations of Africa, begun in *Lieferung 4*, and treating the races native to Oceania and the two Americas, the present numbers complete a series of excellent studies on the biology and history of the races of man. Number 6 provides author and subject indices for the whole series. A noteworthy addition to the anthropologist's library.



THE OLD STONE AGE. *A Study of Palaeolithic Times*.

By *M. C. Burkitt*. *The Macmillan Co., New York*. \$2.50. $5\frac{1}{4} \times 7\frac{1}{2}$; xiv + 254; 1933.

An excellent introduction to the study of prehistory written especially for the student whose training has been along non-scientific lines. Special attention is given to the bases of the subject. The general reader will also find much to interest him, especially those chapters dealing with prehistoric art and the motives underlying the art. The book is adequately illustrated and documented and contains a detailed index.



MENSCHLICHE AUSLESE UND RASSENHYGIENE (EUGENIK). *Vierte Auflage*.

By *Fritz Lenz*. *J. F. Lehmanns Verlag*,

München. 15.30 marks (Cloth); 13.50 marks (Paper). 6 x 8 $\frac{7}{8}$; vii + 593; 1932. This is a reprint of the third revised and enlarged edition, published in 1931, of a well-known general treatise on eugenics. The book is the second of a series of two, the first of which, *Menschliche Erblichkeitslehre* by the late Dr. Erwin Baur, Eugen Fischer and the author of the present volume, has been translated into English.



ZOÖLOGY

FISHES: *Their Journeys and Migrations.*

By Louis Roule. Translated from the French by Conrad Elphinstone. W. W. Norton and Co., New York. \$3.75. 5 $\frac{7}{8}$ x 9 $\frac{1}{4}$; xii + 270; 1933.

An absorbing book, particularly for the general reader. At certain periods of the year all fishes, not only the migratory but the so-called sedentary fishes, change their abode. The journeys of the sedentary are within a restricted area. The migratory fishes often go great distances. In each case there is a definite cause—a requirement for warmer water or richer vegetation or water rich in dissolved oxygen, etc. In the case of the salmon, to which the author devotes several chapters, the comings and goings take place with great regularity. The young salmon, which remain until their second year in the water in which their early development takes place, go down the river by easy stages until the sea is reached, where they bury themselves in its depths. This urge to seek deeper water is held to be due to the fact that their pigment, which formerly was abundant and protected them against the strong sunlight which floods the river waters in the Spring-time, has become diffuse. Their vitality is disturbed and they seek those regions better suited to healthy living. At the same time, the mature salmon, its body gorged with developing eggs or sperm, requires more vigorous respiration, hence the great migration up swiftly flowing streams to those waters containing the greatest amount of dissolved oxygen. Many other types of fish are discussed. In each case the author finds a definite requirement in the animal itself for a particular environ-

ment which causes it to migrate. The book is entertainingly written. It contains many illustrations but unfortunately no index.



CORRELATION OF THE DISTRIBUTION OF THE PROTOZOA IN THE INTESTINE OF RATTUS NORVEGICUS WITH THE HYDROGEN ION CONCENTRATION OF THE INTESTINAL CONTENTS AND WALL. *University of California Publications in Zoology*, Vol. 39, No. 8.

By C. A. Kofoid, E. McNeil and A. Bonestell. *University of California Press, Berkeley*. 25 cents. 6 $\frac{3}{4}$ x 10 $\frac{1}{4}$; 12; 1933 (paper).

The authors report the following findings:

Trichomonas was found in the caecum of all rats examined. It was also present in the ileum in 40 per cent and in the colon in 80 per cent. There is a correlation between the decrease in numbers of *Trichomonas* in the upper ileum and the decrease in pH value of that region.

Hexamitus muris was present in the duodenum in 17 per cent, the jejunum in 7 per cent, the ileum in 57 per cent, and the caecum in 3 per cent of the rats examined. They are present at a pH range of 5.98–8.27.

Chilomastix bettencourti was present in the caeca of 60 per cent of the rats examined, at an average pH of 6.77.

Giardia was present in 60 per cent of all rats examined. It is always found in close proximity to the wall. Giardiasis is primarily an infection of the jejunum, occurring in greatest abundance at a pH range of 6.45–6.52.

Motile amoebae were present in 70 per cent of the rats examined, at an average pH of 6.7.



TEXTBOOK OF GENERAL ZOÖLOGY. *Second Edition, Rewritten and Reset.*

By Winterton C. Curtis, Mary J. Guthrie, with the collaboration of Katharine R. Jeffers. *John Wiley and Sons, New York*. \$3.75 net. 6 x 9; xv + 588; 1933.

LABORATORY DIRECTIONS IN GENERAL ZOÖLOGY. *Second Edition, Revised.*

By Winterton C. Curtis, Mary J. Guthrie and Farris H. Woods. *John Wiley and Sons, New York*. \$1.50 net. 5 $\frac{7}{8}$ x 9; xxxii + 164; 1933.

Although some thirty pages shorter, there is much new material added to that of the first edition of this excellent elementary text. There has been such reorganization

of the subject matter that this second edition is really a new book, retaining, however, the good features of the earlier one. A glossary has been added and the index seems very complete.

The rearrangement of the text has necessitated a new edition of the Laboratory Directions which is designed to accompany it. Here the revisions are less extensive, consisting largely in changes in order.

The first edition of the text was noticed in Volume 3 of this REVIEW, the first edition of the Laboratory Directions, in Volume 1.



ANIMAL BIOLOGY. First Edition.

By Robert H. Wolcott. McGraw-Hill Book Co., New York. \$3.50. $7\frac{1}{2}$ x 9; xvii + 615; 1933.

This book is offered as another addition to the ever-increasing number of elementary zoölogical textbooks. The author has tried to minimize technicalities as much as possible and emphasizes that the volume is not a reference book. The question of animal structure is, on the whole, left to laboratory procedure. The book is divided into five general divisions as follows: Part I, Fundamental Principles; Part II, Protozoa; Part III, Metazoa in General; Part IV, Metazoan Phyla, and Part V, General Considerations. The author has commendably stressed dynamics and the book seems readable and authoritative. The value of this text is enhanced by the number of illustrations, many of which are original or have been redrawn.



HISTORY AND PRESENT STATUS OF THE BREEDING COLONIES OF THE WHITE PELICAN (PELCANUS ERYTHORHYNCHOS) IN THE UNITED STATES. Contribution of Wild Life Division Occasional Paper No. 1.

By Ben H. Thompson. U. S. Department of the Interior, National Park Service, Berkeley. 6 x $9\frac{1}{4}$; vi + 85; no date (paper).

The breeding colonies of the white pelican are now only four. Once they extended over all the western half of North America. Lakes are the natural breeding grounds of this bird and their drainage for agricultural

purposes is considered the principal cause of the reduction in numbers and density. The author does not consider the white pelican in immediate danger of being exterminated but feels that this will eventually be its fate unless means are taken to provide reservations where it can maintain and reproduce itself.



CONTRIBUTIONS TO THE BIOLOGY OF THE PHILIPPINE ARCHIPELAGO AND ADJACENT REGIONS. United States National Museum Bulletin 100, Volume 12. The Fishes of the Families Banjosidae, Lethrinidae, Sparidae, Girellidae, Kyphosidae, Oplegnathidae, Gerresidae, Mullidae, Emmelichthyidae, Sciaenidae, Sillaginidae, Arripidae, and Enoplosidae Collected by the United States Bureau of Fisheries Steamer "Albatross," Chiefly in Philippine Seas and Adjacent Waters.

By Henry W. Fowler. U. S. Government Printing Office, Washington. 50 cents. 6 x $9\frac{1}{2}$; vi + 465; 1933 (paper).

This bulletin contains the fifth part of Fowler's studies of the fishes of the Albatross collections. It includes the main percoid series and embraces a great number of food or market fishes collected chiefly in the Philippine seas and adjacent waters. In the text are 32 black and white drawings. The work is extensively documented and there is a detailed index.



ÜBER DAS VERHALTEN VON STECHMÜCKEN BESONDERS VON ANOPHELES MACULIPENNIS BEI VERSCHIEDENEN TEMPERATUREN UND LUFTFEUCHTIGKEITEN.

By E. Martini and E. Teubner. Johann Ambrosius Barth, Leipzig. 6 marks. $6\frac{1}{4}$ x $9\frac{1}{4}$; 80; 1933 (paper).

This is the report of a comparative study of the influence of temperature and relative humidity on the behavior of several species of mosquitos under laboratory and field conditions. Differences in duration of life and in preference for combinations of temperature and humidity were found to exist in the species studied but these were not the most important controlling conditions in the open.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN, *Lieferung 416. Methoden der Tierhaltung und Tierzüchtung. Haltung und Züchtung von Vorratsschädlingen.*

By Friedrich Zacher. Urban und Schwarzenberg, Berlin. 12 marks. 7 x 10; 104; 1933 (paper).

This number of the *Abderhalden Handbuch* gives biological and ecological information concerning those insects, including moths, injurious to food and clothing, which may be used easily and cheaply for experimental purposes, together with directions for their cultivation in the laboratory. Numerous illustrations of the arthropods described and equipment for their culture, enhance the usefulness of the book.



A CHECK LIST OF NORTH AMERICAN AMPHIBIANS AND REPTILES. *Third Edition.*

By Leonhard Stejneger and Thomas Barbour. Harvard University Press, Cambridge. \$4.00. 6 x 9½; xiv + 185; 1933.

The second edition of this useful handbook appeared in 1923 and is now out of print. This third edition has been brought thoroughly up-to-date by the addition of much new material acquired in the last decade concerning the amphibians and reptiles of North America. As in previous editions the higher groups and genera are listed in systematic sequence and the species in alphabetical order.



CILIATES FROM BOS INDICUS LINN. III. *Epidinium Crawley, Epiplastron gen. nov., and Ophryoscolex Stein.* University of California Publications in Zoology, Vol. 39, No. 1.

By C. A. Kofoed and R. F. MacLennan. University of California Press, Berkeley. 45 cents. 6½ x 10½; 34; 1933 (paper).

REGULATORY DEVELOPMENT IN TRITURUS TOROSUS (RATHKE), by Richard M. Eakin. A ROTARY DISC FOR THE OBSERVATION OF OBJECTS IN PROFILE, by J. Frank Daniel and A. B. Burch. University of California Publications in Zoology, Vol. 39, Nos. 9 and 10.

University of California Press, Berkeley. 25 cents. 6½ x 10½; 13; 1933 (paper).

NEW SPECIES OF PROBOSCIDIELLA AND DEVECOVINA FROM KALOTERMES OCCIDENTIS WAL-

KER, A TERMITE OF LOWER CALIFORNIA. University of California Publications in Zoology, Vol. 39, No. 3.

By Walter W. Lewis. University of California Press, Berkeley. 35 cents. 6½ x 10½; 20; 1933 (paper).

A NEW BLIND ISOPOD, ASELLUS CALIFORNICUS, AND A REVISION OF THE SUBTERRANEAN ASELLIDS. University of California Publications in Zoology, Vol. 39, No. 4.

By Milton A. Miller. University of California Press, Berkeley. 25 cents. 6½ x 10½; 13; 1933 (paper).

STUDIES ON THE STRUCTURE AND LIFE-HISTORY OF OSTIOLUM OXYORCHIS (INGLES) FROM THE CALIFORNIA RED-LEGGED FROG RANA AURORA DRAYTONI AND STUDIES ON THE STRUCTURE AND LIFE-HISTORY OF ZEUGORCHIS SYNTOMENTERA SUMWALT, A TREMATODE FROM THE SNAKE THAMNOPHIS ORDINOIDES FROM CALIFORNIA. University of California Publications in Zoology, Vol. 39, Nos. 6 and 7.

By Lloyd G. Ingles. University of California Press, Berkeley. 50 cents. 6½ x 10½; 44; 1933 (paper).

A NEW SPECIES OF ECHINOID FROM TAMAULIPAS, MEXICO, by Merle C. Israelsky. A NEW GRYPHAEOID OYSTER FROM THE EOCENE OF CALIFORNIA, by Leo G. Hertlein. Transactions of the San Diego Society of Natural History, Vol. VII, No. 22.

San Diego Society of Natural History, San Diego. 6½ x 10½; 9; 1933 (paper).

ANNUAL REPORT OF THE DIRECTOR OF THE MUSEUM OF COMPARATIVE ZOOLOGY AT HARVARD COLLEGE TO THE PRESIDENT OF HARVARD COLLEGE FOR 1932-1933.

By Thomas Barbour. Museum of Comparative Zoology, Cambridge. 6 x 9½; 69; 1933 (paper).



BOTANY

PLANTS USEFUL TO MAN.

By Wilfred W. Robbins and Francis Ramaley. P. Blakiston's Son and Co., Philadelphia. \$3.00. 5½ x 8½; vii + 428; 1933.

This textbook is intended for students who want to be introduced to usable information about plants with the fewest preliminaries possible and it ought to be useful as a textbook in one-term botany courses in agricultural colleges. About half of the

material has been taken from Robbins' *Botany of Crop Plants*. It is well illustrated and indexed.



HOW PLANTS GET THEIR NAMES.

By L. H. Bailey. *The Macmillan Co., New York.* \$2.25. $5\frac{1}{2} \times 7\frac{3}{4}$; vi + 209; 1933.

The title of this book and the reputation of its author are almost sufficient, by themselves, to characterize this introduction to systematics intended for horticulturists and nature lovers in general. Bailey makes a story out of the nomenclatorial history of *Solanum PseudoCapsicum* and *Capsicum frutescens* in order to lead up to the work of the great systematists, and the manner and the spirit in which they worked. It is a cleverly written defense of taxonomy as a living science and a necessary one, and its objective is to remove some of the antagonism to scientific nomenclature, and its occasional changes, that is all too prevalent. The book belongs on reading lists in college botany courses. More than 80 pages are devoted to lists of generic and specific names, with the accents marked to aid in pronunciation. The specific names are also translated.



THREE KEYS TO WILD FLOWERING PLANTS of Connecticut, Southeastern New York, New Jersey and Eastern Pennsylvania.

By Mary F. Barrett, 64 Park Ave., Bloomfield, N. J. 50 cents. 6×9 ; 46; 1933 (paper).

Ecological characters easily recognized by untrained persons have been used wherever possible for purposes of classification; for instance, plants flowering in spring or in autumn fall in different sections, and stem and leaf characters, rather than floral ones, are used to divide up aquatic plants. This manual is meant to serve as a guide for beginners to the larger standard floras; accordingly detailed descriptions of the species are omitted. There is a very explicit and elementary glossary supplemented by illustrations, and a good index of scientific and popular names. It ought to be very useful for "teachers, students,

Scout leaders and other interested persons who want simple aids to identification."



THE STUDY OF CACTI.

By Vera Higgins. *Blanford Press, London.* 7s. 6d. net. $5\frac{1}{2} \times 8\frac{1}{2}$; 164; 1933.

This book has been prepared especially for the amateur cultivator of cacti. Mrs. Higgins has made a very useful book. She assumes that those interested wish to acquire considerable general information concerning these remarkable plants as well as to have a guide for their cultivation. The sections on nomenclature and descriptions of genera are well planned. The volume is illustrated and contains a bibliography, a chart of Britton and Rose's classification, and an index.



THE PNEUMATIC SYSTEM OF PLANTS, ESPECIALLY TREES. *Carnegie Institution of Washington Publication No. 441.*

By D. T. MacDougal and Earl B. Working. *Carnegie Institution of Washington.* 75 cents. $6\frac{7}{8} \times 10$; 87; 1933 (paper).

The gases found in the wood of tree trunks differ little in pressure from the atmosphere but their oxygen and carbon dioxide content is subject to very wide variation. Mac Dougal and Working conclude that their data on the movement of gases through wood, as well as the results of their chemical analyses, indicate that there are facilities for gaseous streaming not yet demonstrated by anatomical studies and that there is no satisfactory explanation for the high CO_2 tensions they find.



AN INTRODUCTION TO LABORATORY TECHNIQUE IN BACTERIOLOGY. *Revised Edition.*

By Max Levine. *The Macmillan Co., New York.* \$1.75. $5 \times 7\frac{3}{8}$; xiii + 289; 1933. This is the second edition of an excellent laboratory manual designed, in its 114 exercises, to give the student an introduction to the important bacteriological procedures. There is a short dichotomous key for the identification of some commonly encountered bacteria, an appendix with

formulas for media, stains, and reagents, and a glossary which supplements drawings of growth habits.



NOTES ON THE FORAMINIFERA OF THE TYPE MERCED AT SEVEN MILE BEACH, SAN MATEO COUNTY, CALIFORNIA. *Transactions of the San Diego Society of Natural History, Vol. VII, No. 21.*

By Roscoe E. and Katherine C. Stewart. *San Diego Society of Natural History, San Diego.* 6 $\frac{3}{4}$ x 10 $\frac{1}{4}$; 13; 1933 (paper).



MORPHOLOGY

A CORRELATION OF THE SILVERLINE AND NEUROMOTOR SYSTEMS OF PARAMECIUM. *University of California Publications in Zoology, Vol. 39, No. 2.*

By Everett E. Lund. *University of California Press, Berkeley.* 65 cents. 6 $\frac{3}{4}$ x 10 $\frac{1}{4}$; 42; 1933 (paper).

This study was undertaken to harmonize the conflicting views concerning the fibrillar system of *Paramecium*. A review of the literature is given and the silverline system as demonstrated particularly by Klein's technique, and the neuromotor system as demonstrated by the use of iron-haematoxylin and Mallory's stain are described in detail and compared. The conclusion is reached that

Because the silverline system confuses parts of three very different structures, the pellicle, trichocysts, and neuromotor complex; because it does not include more than a small part of the entire coordinating system; and because the name "silverline" is descriptive of the technique used to demonstrate the "system" rather than the structures themselves, the term "neuromotor system" is preferable when referring collectively to the conductile elements of ciliate Protozoa.

The study includes excellent line drawings and plates and a literature list.



LYMPHATICS, LYMPH AND TISSUE FLUID.

By Cecil K. Drinker and Madeleine E. Field. *The Williams & Wilkins Co., Baltimore.* \$3.00. 5 $\frac{3}{8}$ x 8; xv + 254; 1933.

An excellent survey of what is known of the physiology of the mammalian lym-

phatic system. The authors, both experimentalists in this field, have drawn their data from anatomy, physiology, pathology and immunology, clearly defining the problems involved and presenting their own well formulated views. As a source book the volume will be most useful in experimental laboratories. Experimental data are arranged in tables and figures. There is a lengthy bibliography, an author index, and an excellently arranged subject index.



DIE EINTEILUNG DES NERVENSYSTEMS NACH SEINEN LEISTUNGEN.

By L. R. Müller. *Georg Thieme, Leipzig.* 6.80 marks. 6 $\frac{3}{4}$ x 9 $\frac{3}{4}$; 74; 1933 (paper).

A short study of the components of the nervous system classified according to performance into (1) the *Systema nervorum pro mundo*, that is the part of the nervous system dealing with the perception of and reactions to the external world (the sensory and motor system), (2) the *Systema nervorum myostaticum*, controlling the tonus of the muscles and tendons, and (3) the *Systema nervorum vitale* which includes the sympathetic nervous system. In the last section an attempt is made to localize centers governing psychical acts. The author concludes with an expression of wonder and awe for the god who invented and created this complicated system. There are nineteen illustrations, mostly diagrammatic drawings.



PHYSIOLOGY AND PATHOLOGY

STUDIES ON THE PHYSIOLOGY OF THE EYE. *Still Reaction, Sleep, Dreams, Hibernation, Repression, Hypnosis, Narcosis, Coma, and Allied Conditions.*

By J. Grandson Byrne. *H. K. Lewis and Co., London.* 40 shillings net. 6 x 9 $\frac{1}{8}$; xii + 428; 1933.

This book is a report on twenty years of research on the eye. The cat served as the chief source of material. However, a variety of animals, as well as man, came under consideration at times. The author

has thoroughly gone over the cat with a precise technique of nerve section and tissue traumatization augmented by use of specific drugs such as adrenalin and ergotoxin. His chief contribution lies in his record of acute and detailed observations on the eye responses in both normal and experimental situations. An excellent index to the book's content is given in the author's conclusion:

The functional relations established in the present studies between the projicient (distance) receptor organs and the mechanisms which mediate the visible, physical reactions (objective components) in approach, avoidance or standstill of the intermediate level, and those which mediate reactions in 'approach,' 'avoidance' and 'standstill' (still reaction) of the higher (psychic) level have their manifest implications from the standpoint of a rational psychology, since every reaction of the individual can be identified as a descendant of one or other of the three basic or pattern forms of reaction in actual approach, avoidance, or standstill of the intermediate and of the lower level; or as one or other of the developmental derivatives (specializations) of the basic reactions as mediated at the higher (psychic) level, viz. reactions in 'approach,' 'avoidance,' or 'standstill' (still reaction). It seems, therefore, that these relations furnish the means for a better understanding of the different factors concerned in the physiology of vision. They also, in my opinion, furnish the means for a better understanding of the physiological processes that underlie, or are associated with, all mental activity, and consequently may furnish in addition the solid foundation for a therapy—preventive and restorative, based upon psychoanalysis—which shall not be too mystifying or metaphysical, but scientific and practical, and above all available for extensive use by the medical practitioner.



THE RISE OF PREVENTIVE MEDICINE. *University of London Heath Clark Lectures, 1931.*

By Sir George Newman. *Oxford University Press, New York.* \$3.00. $5\frac{1}{2} \times 8\frac{1}{2}$; 270; 1932.

A pleasantly written history of medicine compiled from standard sources. The chief criticism that might be made of it is that it seems unnecessarily discursive and general, instead of being precisely aimed at its announced subject, *preventive medicine*. Also the author seems a bit more optimistic than some would be in his evaluation of the present effectiveness and power of public health measures. But this is perhaps to be expected, and is certainly pardonable, in a man of Sir George's

official position. The book is well illustrated and indexed.



CANCER AND OTHER CHRONIC DISEASES IN MASSACHUSETTS.

By George H. Bigelow and Herbert L. Lombard. *Houghton Mifflin Co., Boston.* \$4.00. $5\frac{1}{2} \times 8\frac{1}{2}$; xx + 355; 1933.

In Massachusetts cancer is now considered a public health problem and there have been established 12 state clinics and a hospital for the diagnosis and treatment of this disease. The authors here describe the advantages derived from these clinics and seek to demonstrate the necessity of establishing more of them, not only for cancer but also for other chronic diseases. They desire to develop a program beneficial for the people and still not economically harmful to physicians.

Almost half of this book is composed of statistical tables relative to the population of Massachusetts; incidence and estimated cost of chronic diseases, incidence of cancer in general, and cancer of particular organs; with respect to age, sex, and in some cases, nativity of patients. The data given will be found useful though they do not present facts much different from those observed elsewhere.



LIFE IN THE MAKING.

By Alan F. Guttmacher. *The Viking Press, New York.* \$2.75. $5\frac{1}{2} \times 8\frac{1}{2}$; xii + 297; 1933.

The progress of knowledge regarding human reproduction is here outlined in an interesting manner, and simply enough to be understood by the layman. The theories of the past and those of the present are ably summarized and intermingled with well chosen anecdotes as well as with recorded scientific observations. The subject matter ranges from description of the elements of reproduction to sexual behavior, sex differences and sex determination to sterility and fertility. One section is devoted especially to twins. It seems odd that here the author, who is by profession an

obstetrician, should lay such heavy stress upon physical resemblance as the criterion for distinguishing monozygotic from dizygotic twins, and so little upon the condition of the foetal membranes.

The author's concise and accurate treatment of the subject should serve to give to the layman a better knowledge of human reproduction than he now has and dispel from his mind age-old misconceptions. This end would perhaps be even better achieved if in all places the proven facts had been more clearly separated from mere hypotheses.



COMPARATIVE PHYSIOLOGY OF THE GASTRIC HUNGER MECHANISM.

By Thomas L. Patterson. *New York Academy of Sciences, New York.* \$2.00. $6\frac{1}{2} \times 9\frac{1}{2}$; 218; 1933 (paper).

This paper was awarded the A. Cressy Morrison Prize in Experimental Biology for 1931 by the New York Academy of Medicine. In it Professor Patterson has reviewed critically and summarized all that is known of the gastric hunger mechanism. The following headings, taken from the table of contents, will indicate the scope of the work: (1) The biological significance of hunger (including hunger in the protozoa, metazoa, plants, and higher animals). (2) Comparative physiology of gastric motility in vertebrate and invertebrate animals. (3) Types of animals studied (this includes the Arthropoda, Mollusca and Chordata). (4) The gastro-neuro-muscular mechanism (including the nature of the gastric response, and the influence of stimulation of the sciatic, vagus, and splanchnic on the tonus and motility of the gastric mechanism). Taken together with its bibliography of some 250 references, this is a contribution of the first order. In concluding the author suggests that "a hypothetical tonus center may exist in the brain" and that the "dorsal vagus nucleus may act as a tonal center for the hollow visceral organs (stomach, intestines, etc.) and be somewhat analogous in its action to that of the vaso-motor center in the maintenance of tone of blood vessels."

DER STOFFAUSTAUSCH ZWISCHEN MUTTER UND FRUCHT DURCH DIE PLACENTA.

By H. Schlossmann. *Julius Springer, Berlin; J. F. Bergmann, Munich.* 6.60 marks. $6\frac{3}{4} \times 10\frac{1}{4}$; ii + 73; 1933 (paper).

The author reviews the observations which have been made on the metabolic exchanges between mother and fetus through the placenta and evaluates critically the experimental methods employed and the theories advanced by various workers. His conclusion agrees with that of Slemmons in this country, namely that transmission from mother to fetus, or *vice versa*, is by simple physical processes alone, such as diffusion, and that vitalistic elements play a small part, if any. The contents of the book include: morphology of the placenta, paths of exchange between mother and fetus, metabolism of the placenta itself, responses of the vessels and umbilical cord, experimental methods, transmission through the placenta of carbohydrates, proteins, lipoids, fats, hormones, vitamins, salts and other substances normally found in the blood of mother and fetus, and foreign substances. This is an important monograph, well-written and concise. The bibliography covers eight pages.



THE HISTORY AND EPIDEMIOLOGY OF SYPHILIS. *The Gehrmann Lectures, University of Illinois.*

By William A. Pusey. *Charles C Thomas, Springfield, Ill.* \$2.00. $5\frac{3}{4} \times 8\frac{3}{4}$; xii + 113; 1933.

In these lectures the distinguished author traces the beginning of syphilis in Europe, the development of our knowledge of it, and its epidemiology. Unlike Sudhoff, he does not credit the existence of the disease in Europe in pre-Columbian times. He quotes Oviedo, Las Casas and Dias de Isla, all of whom testify that syphilis was brought back to Spain from the West Indies by the members of Columbus' expedition and thence introduced into Italy. As to "gros mal," references to which Sudhoff found in pre-Columbian edicts, and which he identified with syphilis, Pusey concludes that the term was used to denote,

not syphilis, but epilepsy. The book contains interesting illustrations from early books on syphilis, portraits of eminent syphilologists from Paracelsus to Ehrlich, and an index.



HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 412. Quantitative Stoffwechseluntersuchungen.* Containing following articles: *Bestimmung des respiratorischen Quotienten von überlebenden Geweben*, by Frank Dickens and František Šimer; *Der Helm-Respirationsapparat in seinen verschiedenen Formen*, by Francis G. Benedict; *Messung des Gasstoffwechsels mit der Apparatur nach Simonson*, by Ernst Simonson and Hermann Hebestreit; *Ein Apparat zur Analyse von Gasen aus Respirationskammern für Menschen und Tiere*, by Thorne M. Carpenter.

Urban und Schwarzenberg, Berlin. 8.60 marks. 7 x 10; 184; 1933 (paper).

Dickens and Šimer discuss certain refinements of the Warburg technique useful in determining the respiratory quotient in slices of living tissue.

Benedict contributes a long section on the use of the helmet used in the Nutrition Laboratory of the Carnegie Institution in the study of respiration in man. Carpenter describes the construction, calibration, and use of the gas analysis apparatus developed in the same laboratory.

Simonson has an apparatus for diverting an aliquot portion of the respired air into small rubber balloons, whose contents can be analysed later, the main stream of respired air passing through a gas meter set on the ground wherever convenient. He claims that the subject is much less encumbered by his apparatus than by the Douglas-Haldane one. He gives tables to aid in computation.



STUDIES ON THE NUTRITIVE VALUE OF MILK. II. *The Effect of Pasteurization on Some of the Nutritive Properties of Milk.* *Bulletin* 518.

By W. E. Krauss, J. H. Erb, and R. G. Washburn. Ohio Agricultural Experiment Station, Wooster. 6 x 9; 33; 1933 (paper).

The authors have conducted an experiment on 32 pairs of rats to investigate certain inferior nutritive qualities attributed to milk when pasteurized.

They find that in rats fed milk exclusively, nutritional anemia develops at about the same rate in those given raw as in those given pasteurized milk. The anemia is apparently due to the lack of copper and iron in the milk itself and disappears equally in both groups of rats when these elements are added to their diet. The ash content of the femurs and of the entire bodies revealed the same percentages of calcium and phosphorus in the two groups. The authors also observe that pasteurization destroys about 25 per cent of vitamin B, but does not alter vitamins A, G, and D.

Their results appear conclusive but do not agree in many points with those of other observers, so the controversy on the effect of pasteurization may be expected to go merrily on.



THE HUMAN BODY AND ITS FUNCTIONS. *An Elementary Text-book of Physiology.*

By C. H. Best and N. B. Taylor. Henry Holt and Co., New York. \$3.00 (Student ed.); \$3.75 (Trade ed.). 5½ x 8½; xiii + 417; 1933.

This introduction to human physiology is written in more colloquial language than most textbooks intended for college students, and in general it has been planned for students approaching the subject with a minimum of scientific preparation. Most of the topics of human physiology of current interest are surveyed and there is a commendable tendency to compare the functions of the lower organisms with those of man. There are numerous illustrations, most of them diagrammatic drawings, some of them colored, a pronouncing glossary, and a good index. Because of the freedom from technical language and the care used to explain the basic physics and chemistry of the various processes it should be useful to laymen who happen to have any curiosity about this field.

STUDIES IN THE HISTORY OF OPHTHALMOLOGY IN ENGLAND PRIOR TO THE YEAR 1800.

By R. Rutson James. *The Macmillan Co., New York; Cambridge University Press, Cambridge.* \$4.00 (U.S.A.); 15 shillings net (England). 6 $\frac{1}{8}$ x 9 $\frac{3}{8}$; x + 255; 1933.

The author draws on his own previously published papers for much of the material in this book. The earlier practices and development of ophthalmology are presented in most readable form. As contrasted with modern ideas the practices take on an air of quackery. However, the progress of sound knowledge is traced from the thirteenth century onward. The eighteenth century claims at least half the book. In spite of the record of substantial progress during that time, particularly in the treatment of cataract, the most picturesque reading concerns the performances of quacks who cleverly if not always skillfully treated the royalty of that period.



FOOD, NUTRITION AND HEALTH. Third Edition, Rewritten.

By E. V. McCollum and J. Ernestine Becker, *East End Post Station, Baltimore.* \$1.50. 5 x 7 $\frac{3}{8}$; v + 146; 1933.

A third edition of a book which has been previously mentioned in these pages. The present volume has been rewritten to include all the important findings of recent studies. Written in simple language, those without technical training and particularly the housewife will find it most useful in the proper planning of meals for the maintenance of health in the family as well as an economic expenditure of money. Many theories and claims of faddists and food promoters are exploded. The work concludes with a section on the distribution of vitamins in food stuffs. There is an index.



A TEXTBOOK OF PHYSIOLOGY for Medical Students and Physicians. Twelfth Edition, Thoroughly Revised.

By William H. Howell. *W. B. Saunders Co., Philadelphia.* \$7.00 net. 5 $\frac{3}{4}$ x 9 $\frac{1}{8}$; 1132; 1933.

The twelfth edition of this well-known

textbook brings each chapter into line with modern research. The most extensive additions are on the chemistry of muscle contraction, the hormones, and particularly the vitamins.



BIOCHEMISTRY

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. Lieferung 415. Fermentforschung. Methodik des Nachweises von Abwehrfermentwirkungen.

By Emil Abderhalden. *Urban und Schwarzenberg, Berlin.* 3.50 marks. 7 x 10; 70; 1933 (paper).

This volume describes in detail the author's work on what has been called the Abderhalden reaction. This was originally described as a means of diagnosing pregnancy. Its bases consisted in the idea that the maternal organism elaborates a ferment to protect itself against the foreign protein absorbed through the chorionic villi from the embryo. This protective ferment by enzymatic action destroyed the foreign embryonic material.

Although Abderhalden's original test has proven of little practical value and in general was long ago discredited as a method of diagnosing pregnancy, the general principle of an organism being able to elaborate ferments as a protection against foreign proteins has found considerable credence. He has therefore elaborated the original work and extended it to other conditions (e.g. dementia praecox, eclampsia gravidarum, etc.) which presumably are due to invasion by foreign proteins.



CHEMICAL INVESTIGATIONS OF THE TOBACCO PLANT. Carnegie Institution of Washington Publication No. 445.

By Hubert B. Vickery, George W. Pucher, Alfred J. Wakeman and Charles S. Leavenworth. *With Technical Assistance of Laurence S. Nolan. Carnegie Institution of Washington.* \$1.00. 6 $\frac{1}{8}$ x 10; 77; 1933 (paper).

A biochemical study of mature tobacco leaves detached from the plant and hung in a curing shed was divided into two

parts. In one set of leaves the chemical changes that occur during the usual curing process, and which involve chemical transformations of the greater proportion of the materials in the leaf, were considered. In another set, the leaf bases were allowed to dip into water in order to follow the metabolism of turgid leaves in dim light. The detailed results deserve the attention of specialists. Perhaps the most interesting feature, as far as non-specialists are concerned, is that nicotine appears to be an intermediary product of nitrogen metabolism, and decreases in amount during the curing process in some unknown way.



THE BIOCHEMISTRY OF MEDICINE.

By A. T. Cameron and C. R. Gilmour. *William Wood and Co., Baltimore.* \$7.25.
5½ x 8¾; x + 506; 1933.

The principal clinical applications of biochemistry are described in brief terms and the significance of the chemical tests critically evaluated. It is this, together with the numerous references, that renders this volume a valuable handbook on the subject. The authors consider only those diseases of which the manifestations and symptoms can be explained on a biochemical basis. For purposes of clear exposition it is in effect assumed that the whole question is one of chemistry, and the disease or condition is treated almost as an abstract chemical problem. Especially concise and clear is the outline of human biochemistry which precedes the descriptive part. A useful and stimulating book.



THE PHYSICO-CHEMICAL THEORY OF THE PROCESS OF THE INTERNAL DEFENCE OF ANIMALS. (*Immunity, Tolerance, Specific Chemiotherapy and the Related Phenomena of Hypersensitivity and Idiosyncrasis*) (*A Preliminary Report*).

By David S. Anand, *Infectious Diseases Hospital, Lahore, India.* Rs. 3. 5½ x 8½; xii + 92; no date (paper).

Anand draws an analogy between the par-enteral digestion of proteins in the alimentary canal and the internal hydrolysis of

foreign proteins or antigens in the circulatory system. According to his theory the hydrolysis of antigens is brought about by catalysts derived from the reticulo-endothelial cells. In the process of hydrolysis antigens are converted by successive stages into antibodies. The pamphlet is not well written and is very poorly printed. In the review copy a number of pages are duplicated and several are missing.



ZUM MECHANISMUS DER ENZYMWIRKUNG UNTER BESONDERER BERÜCKSICHTIGUNG DER KRYOLYSE. *Sammlung chemischer und chemisch-technischer Vorträge, Neue Folge Heft 18.*

By F. F. Nord. *Ferdinand Enke, Stuttgart.*

4.30 marks. 6½ x 10; 51; 1933 (paper). An account of the experiments conducted in the Physiological Institute of the Veterinary School in Berlin, on the mechanism of enzyme action, with particular reference to the effects of freezing. Freezing solutions and emulsions and then making measurements of surface tension, viscosity, electric conduction, cataphoretic migration velocity, gas absorption and drop count, showed that in freezing the lyophile colloids underwent an irreversible change. In similar measurements the direction of change, with exception of viscosity, was similar for all colloids. The bibliography contains six titles.



CHEMISTRY AND PHYSICS FOR BOTANY AND BIOLOGY STUDENTS. *Second Edition.*

By E. R. Spratt. *University Tutorial Press, London.* 3s. 6d. 4¾ x 7½; vii + 284; 1933.

A second edition, thoroughly revised, of a book which is highly useful in teaching the elementary biochemistry of plants and animals to students of elementary botany and of biology in general. Many of the sections have been extended. New chapters on magnetism and electricity, electrolytic dissociation, the atom and valency, light, etc. have been added. Each section concludes with a group of experimental problems for laboratory work. The work is abundantly illustrated and is indexed.

BIOCHEMICAL AND ALLIED RESEARCH IN INDIA IN 1932.

Society of Biological Chemists, Indian Institute of Science, Bangalore. Subscription Rs. 2 per year. 5½ x 8½; 86; 1933 (paper).



SEX

TESTICULAR GRAFTING FROM APE TO MAN: Operative Technique, Physiological Manifestations, Histological Evolutions, Statistics.

By Serge Voronoff and George Alexandrescu. Translated by Theodore C. Merrill. Williams and Norgate, London. 5 shillings net. 6¼ x 8½; viii + 125; 1933.

THE CONQUEST OF LIFE.

By Serge Voronoff. Translated by G. Gibier Rambaud. Williams and Norgate, London. 7s. 6d. net. 5½ x 8½; 201; 1933.

These books are representative of two aspects of the work of Voronoff and his co-workers. The first book, addressed to the medical profession, deals with technical details of glandular grafting. It is primarily an attempt to establish the scientific soundness of Voronoff's methods and results. The second book, addressed to the general public, is an attempt to popularize "rejuvenation."

Testicular Grafting is divided into four parts. The first deals with the operative technique which has led to successful transplanting of thin sections of simian testicular tissue upon the tunica vaginalis of the human testicle. In the second part the physiological effects on the grafted individual are described. Even the most sympathetic critical reader will probably fail to be impressed by vague subjective reports that the grafted individual "feels better." The third portion of the book contains a discussion of changes which the grafted tissue undergoes. A number of histological drawings show the initial plasma and cellular infiltration into the graft, the reorganization of the epithelial elements of the seminiferous tubules into insular epithelial structures, and the final disappearance of the epithelial tissue and complete fibrosis of the graft after a period of six to eight years. This section is by far the most important in the book. The last portion of the book is designated

"Statistical Summary." Here a short table gives the indications for grafting and the results obtained on 475 human cases operated on by Drs. Serge and Georges Voronoff. The "results" consist of the unqualified classification of the cases by the operators into "successes" and "failures."

The *Conquest of Life* may do much to discredit Voronoff in the minds of his scientific contemporaries.



MAN INTO WOMAN. An Authentic Record of a Change of Sex. The True Story of the Miraculous Transformation of the Danish Painter Einar Wegener (Andreas Sparre).

Edited by Niels Hoyer. Translated from the German by H. J. Stenning. Introduction by Norman Haire. E. P. Dutton and Co., New York. \$3.50. 5¼ x 8½; 288; 1933.

This book contains an account of an attempted surgical transformation of a man into a woman. Andreas Sparre, a well-known Danish painter, was obsessed with the idea that his destiny was to become a woman, not only in spirit but also in fact. After a long search he found a German physician, Professor Warnekros, an endocrinologist and surgeon of Dresden (his name is mentioned on the blurb but not in the text) who encouraged him in his effort and made arrangements for the surgical transformation. Sparre, outwardly, was definitely male but hormonal blood tests revealed the presence of female sex hormones and later rudimentary ovaries damaged by previous X-ray treatment were found. In several operations the male organs were completely removed and ovarian tissue from a healthy young girl was implanted.

At this stage Sparre had his name changed to Lili Elbe and legally became a woman, had his marriage annulled and became engaged to a French painter. This extraordinary story is finally concluded by the death of Lili Elbe, following an attempt to build-in the necessary apparatus for intercourse and child bearing.

After the first fifteen pages in which the general outlines of this account are given, the book becomes dull reading. The history of the biological as well as the psycho-

logical details, as told chiefly by Sparre to a friend, is too incomplete to make the book of any particular interest beyond that of an extraordinary medical anecdote.



SANE REASONS FOR BIRTH CONTROL. *Partington's Plain Talks No. 1.*

By T. Bowen Partington. *Health and Strength*, London. 6d. net. $4\frac{1}{4} \times 7\frac{3}{8}$; 31; no date (paper).

A LEARNED JUDGE'S VIEWS ON BIRTH CONTROL. *Mr. Justice McCardie Speaks Out. Partington's Plain Talks No. 2.*

By T. Bowen Partington. *Health and Strength*, London. 6d. net. $4\frac{1}{4} \times 7\frac{3}{8}$; 29; no date (paper).

THE SECRET VICE OF YOUTH and Its Effect in Recent Years. *Partington's Plain Talks No. 3.*

By T. Bowen Partington. *Health and Strength*, London. 6d. net. $4\frac{1}{4} \times 7\frac{3}{8}$; 30; no date (paper).

Pamphlets 1 and 2 contain the usual sentimental appeal of the necessity of birth control for the poor people. The sincerity of T. B. Partington, F.I.L., F.R.E.S., is so apparent that one would almost suspect him of advocating a law making birth control obligatory. Incidentally, for a small fee, the author is prepared to give advice to those troubled with sex problems.

The pamphlet on masturbation is very feeble even when compared with the above. The author would certainly benefit by glancing through the works of any of the religious writers on the subject.



SEX AND REJUVENATION.

By G. E. O. Knight. *New World Publishing Co., London.* 1 shilling. $5 \times 7\frac{1}{2}$; 18; no date (paper).

SEX FROM THE STANDPOINT OF YOUTH.

By R. H. Innes. *New World Publishing Co., London.* 1 shilling. $5 \times 7\frac{1}{2}$; 16; no date (paper).

What would be the fate of our civilization if we had not had such men as these authors to guide us?

There will be no more immorality, says Mr. Innes, when free love and nudism become universal. This conclusion is arrived at with such gems of thought as the follow-

ing: "Free love is sexual intercourse sublimated by love."

On the other hand Mr. Knight has at heart the physical ills due to endocrine disfunction. These are many he says, without enumerating, and sex rejuvenation will relieve them. Of course the evil minded might think the author mercenary only because he mentions a certain name and address where sex rejuvenation is to be achieved.



BIOMETRY

USE OF THE EXPONENTIAL YIELD CURVE IN FERTILIZER EXPERIMENTS. *U. S. Department of Agriculture Technical Bulletin No. 348.*

By W. J. Spillman. *U. S. Government Printing Office, Washington.* 10 cents. $5\frac{7}{8} \times 9$; 66; 1933 (paper).

Although the law of diminishing returns has long been a subject of discussion among economists, the earlier members of the profession did little to investigate the actual functional form of the relation between amount of a given factor in production and amount of product. It was left for agronomists and agricultural economists to determine this relation in their experiments on the effect of different amounts of a growth factor supplied in fertilizer on the crop produced. In 1912 Mitscherlich found that an exponential curve of the form $Y = M - AR^x$ describes the relation, while in 1927 Niklas and Miller concluded that it could be better represented by a second order parabola. The author of this bulletin prefers the exponential form, since it is much more successful in extrapolation than the parabola. Formulas are derived for determining the amount of available plant food in the soil, the optimum fertilizer formula to use, and the optimum quantity of fertilizer to apply for greatest profit per acre. Methods and auxiliary tables for the fitting of exponential curves are given. There is a bibliography of 11 titles.



THE NOMOGRAM. *The Theory and Practical Construction of Computation Charts.*

By H. J. Allcock and J. Reginald Jones.

Isaac Pitman and Sons, New York. \$3.00.
5½ x 8½; viii + 209; 1932.

One of the most useful methods for the rapid solution of complex numerical formulae is the nomogram or computation chart. However, this device is still less extensively used than its advantages warrant. The authors have aimed in this excellent book

to combine a discussion of the general theory with practical directions for the construction and use of all classes of computation charts having scientific or industrial applications. In every case, stress has been laid on the details of construction, and examples are given illustrating the various methods employed.



MANUAL OF JOINT CAUSES OF DEATH. *Showing Assignment to the Preferred Title of the International List of Causes of Death When Two Causes are Simultaneously Reported.* Department of Commerce, Bureau of the Census. Third Edition.

Prepared under the supervision of T. F. Murphy. U. S. Government Printing Office, Washington. \$1.00. 5¾ x 9; iii + 255; 1933.



PSYCHOLOGY AND BEHAVIOR

THE INTELLIGENCE OF SCOTTISH CHILDREN. *A National Survey of an Age-Group.* Publications of the Scottish Council for Research in Education V.

The Scottish Council for Research in Education. Mental Survey Committee. University of London Press, London. 5 shillings net. 5¾ x 8¾; x + 160; 1933.

A survey representing a complete cross-section of the Scottish community. The volume will be highly useful to those planning similar investigations in other countries. Roughly 87,000 children born in 1921 were tested, the survey taking place in June 1932. Scholarship tests devised by the committee in charge of the work together with the Terman revision of the Binet scale were made on a thousand children for purposes of comparison with the group tests. The results show

no certain evidence of any significant difference in average intelligence between the boys and girls born in Scotland in 1921. There seems fairly definite evidence that the intelligence quotients of the boys are more

widely scattered than the intelligence quotients of the girls.

The data indicate that the scatter of intelligence is considerably greater than previous surveys have shown.

If I.Q. 90 to I.Q. 110 is taken to represent the range of what is termed the average child, somewhat fewer than half of the school population are in this sense average, and not somewhat more than half, as has hitherto been held. The groups which range themselves on either side of the average and are usually termed superior and retarded respectively are greater than has hitherto been believed.

The report is complete in every detail. The data on individual and group tests are exhibited in tables and graphs in the text. In a group of appendices will be found instructions for giving the tests, forms of tests, etc. There is an index.



A HANDBOOK OF CHILD PSYCHOLOGY. Second Edition, Revised.

By John E. Anderson, Phyllis Blanchard, William E. Blatz, Charlotte Bübler, Barbara S. Burks, Leonard Carmichael, Arnold Gesell, Florence L. Goodenough, Leta S. Hollingworth, Harold E. Jones, Mary C. Jones, Vernon Jones, Heinrich Klüver, Kurt Lewin, Dorothea McCarthy, Margaret Mead, Joseph Peterson, Jean Piaget, Rudolf Pinter, Karl C. Pratt, Mary M. Shirley, Lewis M. Terman, Lee E. Travis, Beth L. Wellman. Edited by Carl Murchison. Clark University Press, Worcester, Mass. \$5.00. 6¼ x 9; xii + 956; 1933.

The editor states in the preface that the revision of this volume "is due chiefly to the great expansion of the field during the past three years and partly to the improved insight of the Editor." While the change in editorial insight may not be apparent, the great growth of the field is plainly evident. Of the twenty-two papers included in the first edition, four, *Children's Philosophies*, *Eidetic Imagery*, *The Feeble-minded Child*, and *The Primitive Child* remain substantially unchanged. Seven papers, *The Methods of Child Psychology*, *Language Development*, *The Social Behavior of Children*, *Learning in Children*, *Children's Morals*, *Order of Birth and Environmental Forces* have been revised and enlarged. Eight papers have been omitted. There

are eleven papers on subjects not previously considered. Of these, Carmichael's review of the *Origin and Prenatal Growth of Behavior*, Pratt's discussion of *The Neonate*, and Gessell's treatment of *Maturation and Patterning of Behavior* are particularly extensive. New papers on more specialized topics include *Locomotor and Visual-manual Function in the First Two Years*, by Shirley, *Emotional Development* by Jones, *The Measurement of Mental Growth* by Goodenough, *Sex Differences* by Wellman, *Speech Pathology* by Travis, and *The Physiological Appetites* by Blatz. *The Gifted Child*, *The Child of Special Gifts or Special Deficiencies*, *The Child with Difficulties of Adjustment* and *The Adolescent Child* are contributed respectively by Terman and Burks, Hollingworth, Blanchard, and Hollingworth. Viewed as a whole the work is well done. Each paper is followed by an extensive bibliography and there is a complete subject and author index.



A CRITIQUE OF SUBLIMATION IN MALES: A STUDY OF FORTY SUPERIOR SINGLE MEN. *Genetic Psychology Monographs*, Vol. XIII, No. 1.

By W. S. Taylor. Clark University Press, Worcester, Mass. \$2.00. 6½ x 9½; 115; 1933 (paper).

In this interesting monograph the author attempts to find whether complete sexual sublimation occurs in healthy, active intellectual men in their twenties and thirties. Of the forty unmarried graduate students from whom he gathered data none had been completely successful in sublimating their sex energies into "higher forms" of activity. In 18 per cent the sexual energies found expression in nocturnal emissions only; 15 per cent found satisfaction in habitual "petting" to the extent of orgasm; 63 per cent practiced masturbation; 8 per cent had intercourse with prostitutes and 13 per cent with women other than prostitutes. In some cases more than one form of sex adjustment was practiced, so that the percentages add to more than 100 per cent. The author concludes that there is in young men an irreducible minimum of sexuality which is never transmuted or sublimated away but which requires and

finds some direct outlet in every case. As to the bearing of his study on the conduct of life he concludes that

no perfect solution for the problem of sex in the young adult male has appeared. Pending the arrival of the perfect social order that never comes, it would seem that any form of adjustment must bring with it both advantages and disadvantages. "Dreams" appear to fail many mature men who have to work hard; "spooning" is a curious make-shift, probably not lacking in social and other disadvantages; "masturbation" fails to develop the normal emotional and social life, if it does not stunt that life; "women," and "prostitutes," as "adjustments," involve several kinds of deprivation and danger, particularly to the women themselves; and early marriage, which suggests itself as an alternative, runs all the risks of youth and inexperience.

Yet, under the conditions, early marriage may be the best way. The few instances that the writer has seen of married graduate students of the type studied were instances of contentment, good work, and good play. . . . As for the economic factor, if it is not true that two can live as cheaply as one, it is nevertheless true that two can live as cheaply as two.

The book contains a bibliography of 134 titles and an adequate index.



CULTURE AND HUMAN BEHAVIOR.

By Sanford Winston. The Ronald Press Co., New York. \$2.50. 5½ x 8; ix + 249; 1933.

In this book the author approaches the study of sociology from the cultural standpoint, which, he concludes, "is basic to an understanding of social institutions and of human behavior in general." A culture—the material instruments and the non-material ways of doing and thinking which a society has developed—is based on societal adjustments to problems of human existence. The biological factors of hunger and sex, the geographical limitations of the environment, the fact that man lives a social life, pose problems to which men attempt different solutions. Those solutions which seem the most satisfactory to a group become stereotyped in its mores.

In his insistence on the functional approach Dr. Winston seems inclined to the viewpoint that all cultural traits are useful and necessary, an attitude dangerously close to Pope's "Whatever is, is right." No doubt a student of a culture should not be hasty in assuming that a trait of which he does not at first sight perceive the use is therefore useless, yet it seems equally

invalid to assume *a priori* that the trait is necessary. After all, different societies have adopted widely different means of solving a problem, so that a custom which one society regards as pernicious is found in another to work well. As organic evolution is the result of individual variation, it is likewise conceivable that societal evolution towards a more perfect adjustment of culture to needs might be facilitated by greater freedom for individual variation in behavior.

The book contains a bibliography of nine pages and an index.



PERSONS ONE AND THREE. *A Study in Multiple Personalities.*

By Shephard I. Franz. Whittlesey House, McGraw-Hill Book Co., New York. \$2.00. 5 x 7½; xv + 188; 1933.

This case history of a man picked up by the Los Angeles police and found to possess a multiple personality has the double merit of being as entertaining as a detective novel and at the same time of being a complete and objective description of an interesting psychopathic case. For this man, time began in February, 1915, during his convalescence from wounds received in action in Belgium, and by no exercise of his imagination and ingenuity could he trace his doings before that time. He was a man of more than average intelligence, and being greatly disturbed at his inability to remember his name or birthplace he had traveled widely, hoping to find some place he could recognize as home. He even attended the services of a number of different religious denominations, experimentally, in an effort to find the one in which he had been reared. Dr. Franz has made a narrative of his attempts to link up the two, or possibly three, personalities that emerged during the course of his questioning of the man, resorting to his record of questions and answers occasionally, quoting letters, and giving facsimiles of the man's handwriting at different times. Incidentally, the self-contradictions contained in the service record supplied by the British War Office are as puzzling as anything else in the book. Finally, as a result of questioning at a particularly favorable time, it was

possible to enable one of the subject's personalities to recognize another, and gradually a partial cure was effected. The book is free from theorizing throughout and both psychologists and general readers will like it.



OBSERVATIONAL STUDIES OF SOCIAL BEHAVIOR. Volume I—Social Behavior Patterns.

By Dorothy S. Thomas, Alice M. Loomis, Ruth E. Arrington, with the assistance of Eleanor C. Isbell. Institute of Human Relations, Yale University, New Haven. \$2.50. 6 x 9; xvii + 271; 1933 (paper).

A technique for observing and recording overt behavior patterns is here fully described. It differs from that of previous investigations because the authors have attempted to group the different modes of social interactions into a few well delimited categories. These are to delineate the reactions of each individual in a given length of time; the proportion of time dedicated to establish contact with other individuals, with surrounding objects, or with none and nothing. In general, behavior depends upon the nature of environment and so examples are given of modification of the technique when applied to a nursery school group, a kindergarten group, a trade school and an adult industrial group.

From this preliminary report very little can be said as to the value of these categories and their significance. Criticism based only on theoretical grounds is out of place because the authors themselves dedicate the greatest portion of this volume to seeking the many subjective and objective sources of error. This deserves unstinted praise and promises much for the conclusiveness of their findings.



THE FIRST TWO YEARS: A STUDY OF TWENTY-FIVE BABIES. Volume III. Personality Manifestations.

By Mary M. Shirley. University of Minnesota Press, Minneapolis. \$2.50. 5½ x 7½; xi + 228; 1933.

The concluding volume of this series, earlier parts of which have been reviewed in

our pages, deals with the development of personality in the babies studied and its quantitative treatment. Observations were made on the babies at home in their natural environment. Much credit is due to the mothers who cooperated in making the records. After such thorough investigation it is found that personality differences are apparent at birth, and in one case a mother noticed a difference in the prenatal activity of twins.

An age trend consistent with that of the group is manifested in every item of the baby's behavior . . . Each baby tends to manifest the various behavior items in approximately the same proportions from age to age. An item that is given up is replaced by another that is consistent with it . . . Each baby exhibits a characteristic pattern of personality traits that changes little with age . . . Babies manifest personality traits that are in harmony with those of their families.

There is a bibliography of 17 items and an index.



CONDITIONED RESPONSES IN CHILDREN. A Behavioral and Quantitative Critical Review of Experimental Studies.

By Gregory H. S. Razran. *Archives of Psychology, Columbia University, New York.* \$1.50. 6 $\frac{3}{8}$ x 9 $\frac{1}{2}$; 120; 1933 (paper).

This monograph, inaugurating a series of reviews of experiments on human and animal conditioning, presents a systematic and comprehensive account of the work on conditioning of children, conducted by Russian and non-Russian workers. It is divided into six parts as follows: I. Experiments from Krasnogorski's Laboratory; II. Experiments from Chuchmarev's and Lenz's Laboratories; III. Experiments from Ivanov-Smolensky's Laboratory; IV. Experiments from Bekhterev's Laboratory; V. Individual Experiments, both Russian and non-Russian; VI. Summary and Conclusions. The treatment is behavioral in that cerebral theories are excluded, quantitative in that statistical measures have been computed from the data, and critical in pointing out factors uncontrolled by the experimenters. The book contains a bibliography of four pages, 19 photographs and diagrams, and 44 tables, and will be a wel-

come contribution to the psychologist and student of conditioning and learning, especially since some of the work included has not hitherto been available in English.



AN INTRODUCTION TO ANIMAL PSYCHOLOGY. The Behavior of the Rat.

By Norman L. Munn. *Houghton Mifflin Co., Boston.* \$3.00. 5 $\frac{3}{8}$ x 8; xxii + 439; 1933.

The literature on the behavior of the white rat is here extensively and systematically reviewed. The author's knowledge of the subject and his objective criticism render the whole a complete and excellent treatise necessary for the student in this field. There are reported the investigations on unlearned behavior, sensory processes, learning processes, symbolic processes. Many of the experiments are quoted at great length and the apparatus and methods used are described in detail. There is a detailed bibliography.



THE DEVELOPMENT OF LEARNING IN YOUNG CHILDREN.

By Lovisa C. Wagoner. *McGraw-Hill Book Co., New York.* \$2.50. 5 $\frac{1}{2}$ x 8; xiv + 322; 1933.

This book traces in an interesting fashion the development of learning in young children. Among the important points discussed are the steps by which the growing individual reaches maturity, his progress in the mastery of his own body, and the technique by which he acquires the skills and methods of response which permit him to take his place in modern society. The author, through contact with nursery school children, points out a number of their behavior problems and suggests methods of dealing with them. This book should have appeal both to the psychologist and the parent or teacher. The value of the work is enhanced by its systematic treatment of the subject as well as its extensive bibliography.

PSYCHOANALYSIS AND MEDICINE. *A Study of the Wish to Fall Ill.*

By Karin Stephen. The Macmillan Co., New York. \$2.50. $5\frac{1}{4} \times 7\frac{3}{4}$; vii + 238; 1933.

This elucidation of psychoanalysis is both penetrating and clear. In discussing the "wish to fall ill" the author gives a full summary of Freud's doctrines. This neurosis, which is often met with in medical practice, according to the author is due to repression also. The mechanism of repression is described—how the need originates, and how, when repression threatens to fail, the inner conflict is resolved by symptom formation.

Examples and illustrations similar to those given by Freud and others are used, but the author apparently draws a great deal from her own experience.



BEHIND THE DOOR OF DELUSION.

By "Inmate Ward 8." The Macmillan Co., New York. \$2.00. $5\frac{1}{4} \times 7\frac{1}{2}$; xvi + 325; 1933.

A former journalist, suffering from dipsomania and for this an inmate of an insane asylum, describes briefly his environment and some of his companions, their thoughts and reactions. With studied simplicity and pathetic humor he seeks to emphasize the tragedy of their situation and thus arouse greater sympathy for their fate. Very interesting is his account of the agitation of his fellow inmates on the question of sterilization of the insane. Their expressed opinions with which he fully agrees show that they possess a clear realization of its significance and probable effects.



DIE VITALE PERSON. *Sammlung psychiatrischer und neurologischer Einzeldarstellungen Band II.*

By Ernst Braun. Georg Thieme, Leipzig. 7 marks. $6\frac{1}{8} \times 10\frac{1}{4}$; v + 79; 1933 (paper).

A psychiatrist considers *Homo sapiens* in his psychological, biological and clinical aspects.

**DE OMNIBUS REBUS
ET QUIBUSDEM ALIIS**

SCIENTIFIC THEORY AND RELIGION. *The World Described by Science and Its Spiritual Interpretation.*

By Ernest W. Barnes. The Macmillan Co., New York. \$4.00. $6\frac{1}{8} \times 9\frac{1}{4}$; xxiv + 685; 1933.

The viewpoint from which this book, a revised form of a series of Gifford Lectures, is written is that "Theology cannot be based solely on human spiritual experience; it must take account of the God of Nature revealed by science." With this end in view the Bishop of Birmingham devotes the greater part of his work to a technically competent and very well written exposition of the present-day results of physics, astronomy, biology and anthropology. Beginning with the dynamics and structure of matter, he deals with space and the rival systems of geometry which have been developed to represent it; the special and general theories of relativity; the electrical theory of matter; heat and light; the quantum theory and Röntgen rays; the solar system; the galactic universe and the great nebulae; the origin of life and the geological record; the evolution of plants and animals; Mendelism; the machinery of evolution; and man's origin and past. This part of the book will be of value to anyone who wishes a connected account of modern scientific results, whether or not he is interested in their bearing on theology.

But there remain problems, both of metaphysics and of theology, to consider. How far does science give us knowledge of a 'real' world? The author's position is that of moderate realism. Objects have a real and independent existence because they exist in the Mind of God. But God is not only a knower but a doer as well. The genetic variations which are the basis of evolution are, by the Bishop's interpretation, the result of His creative activity. Yet there is a difficulty here. Such genetic variations are non-moral. The problem of evil, which has plagued men's minds since the time of Job, still remains to be solved. Yet, although the Bishop recognizes that "all attempts to

take from God responsibility for the nature of his creatures must fail," he is firm in the conviction that a God who has created men to seek after righteousness must be a good God. (Reginald the Office Boy says it is mean to stick pins in the legs of a first-rate scientific man just because he wears gaiters.)



THE UNIVERSE OF LIGHT.

By Sir William Bragg. Macmillan Co., New York. \$3.50. 5 $\frac{1}{4}$ x 8 $\frac{1}{2}$; xi + 283; 1933.

Sir William Bragg's account of the properties of light ranks as one of the best pieces of popular scientific writing of the year. It is based on the Christmas Lectures delivered at the Royal Institution in 1931 and covers about the same ground as the section on radiant energy in an introductory college physics textbook but in a quite

different way. Familiar observations and photographs, some of them colored, of lecture-table experiments have been used in addition to diagrams in order to demonstrate general principles instead of the use of algebraic treatment. Instead of being obliged to use water waves as an illustration of wave motion nowadays a lecturer can call upon popular experience with radio waves, with some gain in clarity. He has taken as the thread of his story the old rivalry between the corpuscular and the wave theory of light "which has been one of the most powerful contributors to the development of science." Everything has been nicely calculated to arouse the interest of an inquiring boy and to start him looking for illustrations of these self-same principles in things he can see about him, automobile headlights, the lustre of fabrics, and meteorological phenomena, for instance, and this isn't a bad result for a book to produce in anyone.



THE QUARTERLY REVIEW of BIOLOGY



PHYLOGENETIC TAXONOMY OF PLANTS

By JOHN H. SCHAFFNER

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TAXONOMY is the science of classification of plants and animals according to some principle, purpose, or philosophy held by the classifier. In early times men classified living things according to obvious similarities in appearance and obvious similarities in use. Many "kinds" of plants and animals were recognized and named before there was any development of real biological science and these kinds were often arranged into simple systems for the various purposes and uses to which the organisms were put.

The Emperor Shen Nung, the second ruler in the Chinese period called the "Age of the Five Emperors," was apparently the real historical "father of botany." His rule is usually dated from B.C. 2838-2698. His book is called *Shen Nung's Tree and Herb Book* and consists of three volumes. It has come down with some changes, losses, and additions, as would be expected, to the present time. It was written especially for medical purposes but also gives information in regard to food plants and industry. Besides various kinds of minerals and animals, it contains a total of 252 species of

plants and these along with the minerals and animals are classified according to their supposed medicinal value or properties into three groups—1. High grade; 2. Medium grade; 3. Low grade. Later Tung Chun in the reign of Hwang Ti (2697-2513 B.C.) wrote a book of two volumes entitled *Manual for Recognizing and Collecting Medicinal Plants*. In the ancient Mosaic law the animals were grouped into various categories and these groups were then divided as clean or unclean for food. The main purpose of the classification was to distinguish animals to be used for food and ceremonial purposes from those which were to be avoided.

With the advance of biological knowledge, more elaborate and more strictly scientific systems were developed. Aristotle (384-322 B.C.) developed a classification of plants and animals which, although crude from our point of view, gave a decided impetus to the study of taxonomy. Eresios Theophrastos (370-285 B.C.) has been called the "father of botany." He described about 450 cultivated plants and classified them as herbs, undershrubs, shrubs and trees, regarding

the trees as the very highest expression of plant development. Down to the sixteenth century practically no further botanical taxonomic knowledge was developed and during the 200 years of the time of the herbalists the object of plant classification and description was still to enable interested persons to identify medicinal plants. The main interest of the herbalists in taxonomy was still about the same as it had been for Shen Nung, Tung Chun, and Theophrastos.

Coming down to modern times, the first system of plant classification that came into quite general use was Linnaeus' Artificial System, first outlined in 1735. Tournefort had established the genus concept by the year 1700 and had given definite names and descriptions to a large number of genera. In 1753 Linnaeus established the binomial system of nomenclature in his *Species Plantarum*, which has become the primary starting point for our present botanical practice in determining plant names. In this work, Linnaeus divided plants into 24 classes, 23 classes of flowering plants (Phanerogamia) and one class of flowerless plants (Cryptogamia). Within the classes, orders were recognized and the orders were divided into genera. Linnaeus recognized the fact that his system was purely artificial.

In 1789, de Jussieu developed a "Natural System" and this was a new starting point for plant taxonomy. This "Natural System" was, of course, not developed on any evolutionary principle but was nevertheless a great step in advance toward a true natural system of taxonomy. De Candolle in 1813 developed an improved system of natural classification and important additions and improvements were also made by Stephan Endlicher, Adolphe Brongniart, Alexander Braun, John Lindley, and many others, both for the higher and lower plants. In 1862-1880, Bentham

and Hooker published the three volumes of the *Genera Plantarum*, with a classification which reflected many of the features of the systems of de Jussieu and de Candolle, but was nevertheless a decided improvement. The classification followed in the *Genera Plantarum* became the established system in America, through the influence of Asa Gray and others, until it was replaced in recent years by the Engler System as developed in *Die Natürlichen Pflanzenfamilien*. The Engler System of classification appeared in its first form in 1886. The Engler System is a revised and improved form of the classification of Eichler, first proposed in 1876 and further developed in later years. Wettstein has also followed the Engler System with no essential modifications. These present, standard taxonomies are regarded as true evolutionary systems but they were, nevertheless, based largely on the teleological and anarchistic theories of evolution developed by Lamarck and Darwin as well as on very superficial morphological analyses.

A new era was initiated by Bessey in developing the phyletic viewpoint of taxonomy. Bessey appropriated the best features of the Bentham and Hooker system and gradually developed a consistent phylogenetic taxonomy of the entire plant kingdom, which is more or less in harmony with our present view of the theory of descent. The germs of the Phyletic System are found in Bessey's paper, "A Synopsis of the Larger Groups of the Vegetable Kingdom," published in 1894. Bessey's system was gradually developed with many important papers on the subject until the time of his death in 1915. Among his more important contributions are papers and synopses that appeared in 1897, 1907, 1909, 1910, and 1915.

Gradually the new viewpoint began to

influence the taxonomic thinking of a few isolated taxonomists although the vast majority both in America and the rest of the world followed the Engler system without question as though it were the final consummation of all taxonomic knowledge. In 1905 Hallier published an outline of classification of the flowering plants which had many features in common with the systems proposed by Bentham and Hooker and by Bessey. In the same year the writer published his *Laboratory Outlines for General Botany* in which the study of the evolution of the flower of Angiosperms began definitely with *Sagittaria* and *Ranunculus* and ended with *Taraxacum*. In 1910, in the second edition, the magnolia was placed before these as being a more suitable type for the study of the primitive angiospermous flower. In this edition was also included a "tree" of the 16 phyletic groups, the Diatomeae and the Conjugatae being then regarded as entirely distinct phyla. From 1905 to 1922 the writer published a series of papers on "The Classification of Plants" based on the phyletic idea and a new series, "Principles of Plant Taxonomy, I-X" has been published in 1924-1931. In 1928, the author also published a *Field Manual of the Flora of Ohio* in which the Phyletic Taxonomy is consistently developed.

In the meantime, some important European contributions have been made to the subject by Arber and Parkin, by Mez with his application of serological methods to the problem of plant relationships and more recently by Hutchinson and by Schellenberg.

Botanical science has at last advanced far enough, that a rather conclusive taxonomy can be established on a true, evolutionary basis. But in order to discern the taxonomic system of plants properly, so as to avoid reasoning from the particu-

lar to the general, the botanist must certainly be familiar with the general characteristics of the whole plant kingdom, have a knowledge of life cycles, and also must be somewhat acquainted with paleontology and with ecological relations. The principle of organic change along definite lines will then become profoundly evident. On the other hand, the principle of stability is just as evident. Indeed it is so evident that, with a universal process of evolution accepted as the cause of the progression and diversity in the plant kingdom, it becomes at first difficult to realize that large numbers of plant and animal genera have remained unchanged for hundreds of millions of years. In addition to the principles of organic change and organic stability another peculiarity is in evidence. Sooner or later sexual incompatibility evolves between the members of two segregated groups and thus they become permanently isolated from each other with no further possibility of intermediates through hybridization. This incompatibility may also evolve between closely related forms. Thus completely isolated, narrow lines may be established which may continue through many geological ages, as for example *Ginkgo* and *Equisetum*.

Biological taxonomy has gone through much the same process as the classification of the chemical elements. Whereas only a few years ago the elements appeared to represent a more or less chaotic system, it now, in consequence of the new knowledge brought about through the discovery of radioactivity, appears to be such a perfect cosmos that the chemist is able to successfully predict the existence and general nature of missing elements. Although biological units are infinitely more complex than the chemical elements, the taxonomist is, nevertheless, able to postulate the necessary steps in the evolutionary

progression and actually finds such series even in the fragmentary material which is available in the living forms and the still more fragmentary material of the fossil record. He can with a considerable degree of assurance reconstruct the general characters of life forms evolved during the geological cons.

PRINCIPLES AND DICTA OF TAXONOMY

Before proceeding to the development of the phyletic system of classification, a number of the more important dicta involved in the theory of evolution and some fundamental principles, on which the author's taxonomic procedure is based, will be presented.

1. Taxonomy is based on assumed phylogenetic relationships which come about through evolutionary processes.

2. Taxonomy must reflect a correct evolutionary theory and any evolutionary theory must itself be in harmony with a correct taxonomy. Evolution is not teleological in the sense that the structures evolved are necessarily of any special use. There is no correspondence between fundamental evolutionary movements and the taxonomic system on the one hand and the environment on the other. The same taxonomic changes take place in the most extreme differences of habitat and a change of habitat may bring no corresponding change in the taxonomic structures.

3. In developing the general system, all characteristics are taken into account,—morphological, physiological, and chemical, as also the life cycle; but so far as possible the attempt is made to define the groups in morphological terms.

4. The taxonomic characters are of different dimensions and categories. The more fundamental differences are usually the greatest and are generally unchangeable, while minute specific or varietal potentialities are less stable and their

addition or loss does not disturb the fundamental system, although inhibiting or modifying factors may prevent a proper ontogenetic expression to a greater or less degree.

5. The entire taxonomic system is developed through the addition of segregative and progressive potentialities to the protoplast. In general the segregative additions are responsible for the larger and smaller phyla or phyletic lines while the progressive movements result in a more and more complex system in the individual lines as well as in the greater divergence in the characters of homologous parts. One organ or part may, however, be advancing decidedly while another remains stationary.

6. With the addition of a new potentiality old potentialities may be prevented from coming to expression entirely except in an unusual environment, or the old potentiality may be active in only a limited period of the ontogenetic cycle; thus recapitulations of ancestral activities may be evident either in the embryonic or juvenile stage, in the intermediate ontogenetic development, or at the very end of the ontogenetic cycle. Recapitulations at the end of the ontogenetic development are very common in the higher plants. These recapitulations often give definite indications of relationship. On the other hand, the new potentialities may also change the character of the embryo.

7. All of the fundamental movements which are responsible for the advancement in complexity of the taxonomic system are orthogenetic, irreversible, and mostly determinative and it is for this reason that there is a taxonomic system.

8. In the evolutionary movement there is little or no loss of fundamental potentiality acquired by the protoplast, although certain homologous parts of the

developing individual may undergo degeneration; but so-called unit characters due to Mendelian hereditary factors are often unstable and subject to loss.

9. In general, phagophytic plants are no more simple than the holophytic and may evolve into exceedingly complex systems as in some of the higher Fungi.

10. Characters or systems may come to apparent stability long before the determinate limit of the system is reached.

11. The fundamental, progressive movements have given rise to ten progressive stages which through destructive elimination have been reduced to exactly seven living subkingdoms or divisions of plants, with greater or smaller gaps between them, and each higher subkingdom always possesses all the fundamental potentialities of all the stages below it.

12. The subkingdoms, being easily delimited, determine the fundamental limits within which classes are recognized. These classes are the result of important segregative developments. Thus a class becomes: "The largest, definitely determinable, apparently monophyletic group in a subkingdom."

13. The Class is the unit of classification in the broadest sense. Classes showing a probable relationship are aggregated into Phyla, which are the largest, recognized phyletic groups. Subphyla may also be recognized, when the supposed relationship of certain classes is very obscure. On the other hand, the Classes are divided successively into smaller divisions—Subclasses (if expedient), Orders, Families, Tribes, Genera, Species and the subdivisions of these categories. The Species may be designated as Linneons containing Jordanons or varieties. Beyond these are the unit characters depending on unit potentialities or genes. Jordanons and unit characters must be distinguished from fluctuations. Polyploidy and chro-

mosome irregularities are of little importance in taxonomy except in the problem of genetic varieties and forms and as indicating cytoplasmic disturbances brought about by past hybridizations, failure of reductions, or other abnormal chromosome reactions during karyokinesis.

14. The orders are to be limited arbitrarily and, unless an urgent reason exists, are not to exceed seven in any class, or subclass if the class is so divided.

15. In recognizing families, historical development is at present to be the primary guide, new segregations being made only in case of a very complex family aggregate. The same principle should apply to the segregation of genera and species, since the multiplication of names because of trivial differences makes the system impractical. When much division of the older groups seems advisable, the segregation can be shown by establishing subgroups, as subfamilies, tribes, subgenera, etc.

16. The fact of the accumulation of characters and the development of complexity is a guiding principle in taxonomic sequence, the simpler systems being taken first and the most complex last. Paleontology and ontogeny, when known, indicate, when properly interpreted, the proper sequence of the taxonomic series. The complexity of the system is to be judged by complexity of potentiality in the protoplast and not by mere reductions or simplifications of special parts expressed in the ontogeny. Usually a simplified organ represents a more complex reaction system than one with a greater multiplication or repetition of parts. The simpler protoplasmic units came first and the more complex evolved from them.

17. When two phyletic lines are about on a level in their lower members, the one evolving to the greater complexity at the upper limits is to be taken last. Thus the

Ferns precede the Lycopods, Pinales precede Taxales, and the Monocotyls precede the Dicotyls.

18. The details of the taxonomic system must change with advancing knowledge, but there should be no change necessary in the fundamental aspects of the system, if it is established on correct evolutionary theory.

19. The rules of nomenclature are to be determined by general international agreement; such rules should, however, not be so arbitrarily binding as to impede progress or prevent the correction of mistakes committed by the ignorance of the past. At present no final dictum should be made respecting the larger taxonomic groups.

20. The taxonomic system is to be determined by a direct appeal to the facts involved and by the free exercise of the reason, without appeal to any authority whether of high or low repute.

21. Changes and improvements in taxonomy are not to be neglected on the plea of inconvenience, and all treaties and systems not in accord with the latest established facts are to be studied only in the light of historical development.

THE TEN FUNDAMENTAL PROGRESSIVE STAGES IN THE EVOLUTION OF PLANTS

If it is assumed that all plants came from a common origin and not from a number of distinct centers of creation, then the first step in the organization of a general system of classification according to the phylogenetic principle is to make an inventory of the accumulation of the general fundamental hereditary potentialities of the protoplast from the lowest to the highest types of complexity. Such an inventory can, of course, also be made in the classification of any single phylum or smaller group. The general inventory reveals a succession of ten fundamental

stages or subkingdoms, seven of which are definitely represented by known living forms.

I. ARCHEOPHYTA. The genesis of life or the transition of the first living things from the nonliving. This is assumed to have been the organization of certain types of molecules into colloidal particles of a peculiar composition or pattern which gave to these particles or autogens the fundamental and distinctive properties of living things. The original autogens were holophytic with the following properties possessed by all present autogens of living organisms. They were autonomous self-perpetuating particles which in proper conditions and surroundings reproduced their own specific composition (assimilation). They had the power of self-division, which is a characteristic property of all the organized units of higher rank in the protoplast as well as of the protoplast as a whole. They had the power of correlative interaction so that a number of the ultimate living units are held together in a limited or unitary reaction field. They had the property or power of intermittent mutation by which in isolated cases, a new pattern in one or more autogens is produced and after the mutation occurs the mutated autogen continues to reproduce only the new form by assimilation indefinitely, in some cases apparently permanently, in others until another mutation again brings a change. Aggregations of the simple uniform autogens were then the first bionts and these by intermittent mutation gave rise to bionts of various mixtures of autogens, some of which might evolve as parasites or saprophytes. Perhaps some of the disease-producing plant and animal filterable viruses are of this nature.

II. PROTOPHYTA. The second great progression and transition to a new condition of living things was caused by the organi-

zation of the more complex bionts into definite protoplasts or cells and this marks the beginning of organisms in contradistinction to the primitive bionts. The autophytic bacteria represent the lowest known stage of unicellular organisms. The organisms of this second stage are apparently entirely without sex-potentiality and mostly have a very primitive type of nucleus, typically not limited by a definite nuclear membrane and are also mostly without normally organized plastids. They evolved to the colonial and multicellular condition and to a slight degree of differentiation. They evolved chloro-holophytic, saprophytic, and parasitic forms of various types, ciliated and nonciliated cells, and two chlorophyll types, a large group in which the chlorophyll is associated with a blue pigment and a small mother group with a normal, pure chlorophyll condition, a typical nucleus with nuclear membrane, and typical chloroplasts.

III. NEMATOPHYTA. The third stage in the ascending scale is the evolution of the sex potentiality with a well organized nucleus and chromosomes, giving rise to a new type of heredity (Mendelian heredity) with fertilization and reduction as normal phases in the life cycle. Several phyletic lines were now segregated, giving rise to various types of life cycles, the usual ones being the simple haploid sexual cycle, the simple diploid sexual cycle, the primitive alternation of generations cycle, and the peculiar conjugate phase cycle of the higher fungi. The lowest forms are unicellular and these soon lead up through colonial forms, mostly filamentous, to multicellular individuals with a considerable degree of differentiation. The sexual condition progresses from isogamy through various stages to typical heterogamy and finally to the condition where secondary sexual states and dimorphisms

in the vegetative tissues regularly precede the formation of the hetero-gametes. The multicellular plants of this stage are mostly hermaphroditic with the unisexual condition frequently appearing in the various evolving lines. There are chloro-holophytic, parasitic, and saprophytic groups.

IV. PROTOBRYOPHYTA. There is an enormous break or hiatus between the living Nematophyta and the next higher stage of living plants, the Bryophyta. This break must represent a subkingdom of plants intermediate between the lower green Algae and the present lowest Bryophytes, but no such plants are known, either living or fossil. During the progression of this interval a new type of typical green plant was evolved which had a typical antithetic alternation of generations life cycle with independent gametophyte and parasitic sporophyte and with characteristic multicellular ovaries and spermaries. This typical antithetic alternation of generations life cycle is characteristic of all the higher plants and, along with other prominent characteristics, indicates that the Metathallophyta had a monophyletic origin out of the Thallophyta.

V. BRYOPHYTA. As stated, these plants have a typical antithetic alternation of generations. The sporophyte is completely parasitic, one-phased, unbranched, and determinate in growth, the terminal bud being destroyed in the reproductive process. The gametophyte evolves in various ways, but shows two distinct stages of progression. In the lower type the archegonia are completely superficial organs, while in the highest (*Anthoceros*) the venter of the archegonium is organized from thallus tissue below the epidermis. This condition is characteristic of all the lower Pteridophyta. The sporophyte evolves from a spherical sporangium devel-

oped inside of the archegonium venter to a much more elaborate structure containing a foot, seta, hypophysis, with stomata and chlorenchyma, and sporangium. The spore tissue of the sporangium also shows a progression from the condition in which the entire center is sporogenous to a condition in which there is a completely sterile central columella. In various minor phyletic lines there is a progressive transition of the gametophyte from the hermaphroditic to the unisexual condition.

VI. PROTOPTERIDOPHYTA. There is a prominent hiatus between the living Bryophyta and Pteridophyta. A few fossils have been found which apparently belong definitely to this gap. The fossil plants like *Rhynia*, *Hornea*, and *Psilophyton* were typical transition forms. The sporophyte had developed prominent long-continued vegetative growth and dichotomous branching but had not evolved definite roots and leaves. It had continued the terminal cauline sporangia characteristic of the Bryophytes. The fossils so far discovered apparently all belong to the Lycopod alliance.

VII. PTERIDOPHYTA HOMOSPORAE. Passing from the Bryophyta to the living Pteridophyta a number of very important fundamental potentialities are added to the reaction system. There is a change from a determinate to an indeterminate sporophyte and from a permanently parasitic condition to a parasitic phase continuing only through the juvenile period. In other words, there is a two-phased sporophyte. The reproductive process is shifted from the central or stem axis to an appendage (the leaf). Reproduction does not bring on death but the sporophyte continues to grow indefinitely through any number of reproductive periods. The gametophyte has a strong tendency to become small and short-lived. The archegonium has a short neck and its venter is imbedded

in the tissue of the thallus. There is a progression from a typically hermaphroditic condition to unisexuality at the highest levels. A definite branching system is usually evolved in the sporophyte, and is either dichotomous or monopodial. A well-developed vascular system has been evolved, with a cambium layer in the fern-horsetail alliance and from this condition there is a progression to closed, scattered vascular bundles. Some phyla develop flowers (determinate, sporophyll-bearing shoots) and some continue in the flowerless condition. The sporophyte has developed roots and leaves of some sort. In the progression through this subkingdom, there is also a strong tendency to differentiate sporophylls from foliage leaves in the higher levels.

VIII. PTERIDOPHYTA HETEROSPORAE. The most remarkable addition to the fundamental hereditary potentialities at this level is the shifting of the time of sex-determination from the ontogeny of the gametophyte to the sporophyte. In the lowest levels the determination takes place near the very end of the ontogenetic development of the sporophyte. Such a movement was, of course, already foreshadowed in the homosporous level. This shifting of the time of sex determination results in heterospory and highly dimorphic unisexual gametophytes. There is no such extreme sexual dimorphism between male and female individuals in any group of organisms as in the heterosporous plants. The gametophytes are much reduced, short-lived, and dependent on the parent sporophytes for their food supply. As in the homosporous level, some have flowers and some are flowerless. The leaves in the highest species are at least always of three types, foliage leaves, megasporophylls, and microsporophylls.

IX. GYMNOSPERMAE. Plants evolving to this level have added a large number of

new fundamental potentialities to the complement already acquired by the cell in its phylogenetic progression. The gametophytes are completely parasitic, the male gametophyte (pollen grain) becoming a two-phased parasite through the evolution of the pollen tube. The sporophyte is not only two-phased in its development but a resting phase is intercalated between the parasitic and independent phases. Along with the complete parasitism of the female gametophyte has come the evolution of the seed which is an elaborated megasporangium. Most of the phyletic lines have evolved flowers but several flowerless members are still continued, as in the living *Ginkgo* and in the carpellate plants of *Cycas*. In the highest types the inflorescence is well developed and the flower is reduced to the extreme limit. There are various progressive advances in certain phyletic lines which attain the same level as the corresponding structures in the Angiosperms, the three-celled male gametophyte for example.

X. ANGIOSPERMAE. This is the culmination stage or subkingdom of the plant kingdom. The Angiosperms did not have their origin in any of the living Gymnosperm groups, but are a more advanced stage coming from the same source as the Gymnosperms, namely the eusporangiate, homosporous Ferns. The Bennettitales, which have sometimes been regarded as the point of origin for the Angiosperms, cannot be the ancestors because of the very peculiar condition of their gynecia. The Angiosperms develop their ovularies in all the hypogynous groups from the megasporophylls themselves. Nor can the Caytoniaceae be regarded as in the direct ancestral line, for they roll up their megasporophylls from the tip while the Angiosperms do so from the midrib. The Caytoniaceae and their relatives may be members of a great class or even sub-

phylum of primitive Angiosperms. The Angiosperms have evolved a closed megasporophyll (carpel) and added a new organ, the stigma. They are all flowering plants and all the higher forms developed inflorescences, which in rare cases were reduced again to a single flower. The gametophytes are extremely reduced and the female gametophyte usually develops two sexually potential cells in addition to the single egg. At the time of fertilization of the egg, the two "polar nuclei" fuse with the second sperm and thus produce by a triple fusion an endosperm or xenophyte. The pollen tube is a much more extensive and efficient parasite than in the Gymnosperms. There is a consistent evolution of the flower in all the phyletic lines and in many cases the extreme limit is reached in the epigynous condition. The flower progresses regularly from the primitive, strobilus-like, apocarpus, choripetalous condition to the syncarpous condition and finally to a unilocular ovulary, which condition is mostly attained at the limits whether the flowers evolve epigyny or remain in the original hypogynous state. The transition region between the vegetative parts and the sporophylls shows especially important evolutionary activities, which give rise to peduncles, involucre, generalized perianths and perianths with a specialized calyx and corolla. Such structures, aside from the peduncle, are but slightly evolved in the Homosporous and Heterosporous Pteridophytes and Gymnosperms, although a primitive perianth or involucre is sometimes present. The plant body of the Angiosperms has evolved into a great number of special types, many of which are not represented in any of the three preceding subkingdoms of vascular plants. The annuals are especially abundant. The flowers and fruits show endless developments of complex symmetries,

colors, and color patterns. The evolution of the zygomorphic flower, which appears very rarely in crude form in the Gymnosperms has been attained in many of the phyletic lines. This highly evolved complex beauty is very extreme in some lines when compared with the simple spirally symmetrical beauty of the lower flower types found in the Lycopods, Selaginellas, Horsetails, Cycads, and Conifers.

When one makes a summation of all these fundamental potentialities enumerated above for the ten successive stages and then remembers that there are many more which have not been listed, it becomes evident that the protoplast of an Angiosperm contains such a great complexity of fundamental potentialities, to say nothing of the large number of segregative group potentialities and the host of superficial unit factors or genes, that the nature of the basis for these properties in the protoplasm becomes practically incomprehensible.

THE SEVEN SUBKINGDOMS AND THE CLASSES OF LIVING PLANTS

Of the ten stages or subkingdoms enumerated above, seven are represented by the living plants of the present age, namely, Protophyta, Nematophyta, Bryophyta, Pteridophyta Homosporae, Pteridophyta Heterosporae, Gymnospermae, and Angiospermae; and with these established we are prepared to segregate the large units of classification, namely the classes. As stated in the enumeration of principles above, a plant class may be defined as the largest, definitely determinable, and apparently monophyletic group in a subkingdom. Since the subkingdoms can be definitely delimited at least in so far as living species are concerned, the class also becomes a very definite unit in developing the taxonomic system. Each class

should stand for some prominent and definite character or group of characters. In establishing classes some consideration should, however, be given to the practical side of the problem. Thus about 50 definite unit groups or classes can easily be recognized and there should not be much difference in treatment between different taxonomists, provided the present definition of a class is accepted.

The segregative characters for the classes will be given below in the class synopses under each phylum, although as stated they are originally segregated within the limits of the several subkingdoms or stages. According to a liberal interpretation of the class definition, including the living classes and the well-established fossil classes, there are 29 of these groups in the Thallophyta and 22 in the Metathallophyta. These are distributed in the ten subkingdom stages as follows: Archeophyta, none definitely known to exist; Protophyta, 5; Nematophyta, 24; Protobryophyta, none known to exist; Bryophyta, 5; Protopteridophyta, 1 (fossil); Pteridophyta Homosporae, 4; Pteridophyta Heterosporae, 4; Gymnospermae, 6; Angiospermae, 2.

The classes which show a probable relationship are collected into the great phyla and of these there are about 15, with several recognized sub-phyla which some might think should be raised to phylum rank. On the other hand, the classes are the great units for subdivision into smaller and smaller groups, as stated in the outline of principles, until the species are reached, which are the general unit groups for botanical nomenclature. The criteria for these divisions are more or less arbitrary, for up to the present time no one seems to have been able to give the earmarks that would serve for a definite treatment. According to the writer's rules of procedure, the number of

orders is usually limited to seven or less for a class, or a subclass in case subclasses are necessary. According to this basis of segregation there are 200 or less well-established orders of living and fossil plants, or about an average of four per class. Many classes, of course, have but one or two orders while the most complex class, the Dicotylae, has 40 distributed among 8 subclasses. The orders now recognized as well-established groups in the author's system number 94 for the Thallophyta and 88 for the Metathallophyta. In determining the number of orders to be established in a complex

class we have a problem similar to that in deciding how many large main branches a large elm tree has, for example. Of course, there are many more orders of named fossil plant remains but most of these are still imperfectly known and so cannot take their place definitely in the system at present.

The orders may be divided into sub-orders, if one desires to make a greater segregation before the family group is reached. Below a synopsis of the great phyla is presented and this is followed by a synopsis of the classes and subclasses in each phylum.

SYNOPSIS OF THE PLANT PHYLA AND SUB-PHYLA

- I. Plant body unicellular, colonial, or multicellular, frequently filamentous; ovary when present never an archegonium; nonsexual plants or with a simple haploid or a simple diploid sexual cycle, sometimes with haploid and conjugate phases, the conjugate phase with binucleate cells; sometimes with an alternation of haploid and diploid generations, but then not of the typical antithetic type, the diploid sporophyte never having a parasitic existence or proper parasitic phase on the parent gametophyte, but originating from a free spore or zygote. (THALLOPHYTA).
- A. Cells typically with poorly differentiated nuclei and chromatophores and with a primitive type of nuclear division; motile or nonmotile, with or without chlorophyll, never with a pure chlorophyll-green color; reproduction by fission; resting spores or cells commonly present.

Phylum I. SCHIZOPHYTA.

- B. Cells with well differentiated nuclei and if holophytic usually with definite chloroplasts; with or without chlorophyll; plants green or colorless or variously tinted by coloring matter other than chlorophyll.

- (A) Unicellular saprophytic plants without chlorophyll, having a plasmodium stage of more or less completely fused cells, mostly amoeboid in nature, from which complex sporangium-like resting bodies are built up; sexuality primitive; resting spores finally liberating flagellate or amoeboid cells.

Phylum II. MYXOPHYTA.

- (B) Plants not developing a plasmodium, the cells usually covered with a wall during the vegetative phase.

1. Unicellular or filamentous plants containing chlorophyll, either brown and with silicious, two-valved walls or green with complex chromatophores and the walls not silicified, conjugating cells not ciliated, isogamous; with a simple haploid sexual cycle, the reduction division probably always in the zygote.

Phylum III. ZYGOPHYTA.

- a. With silicified cell walls and brown coloring matter. Subphylum 1. DIATOMEAE.
- b. Not with silicified walls; cells green. Subphylum 2. CONJUGATAE.
2. Plants not with silicified two-valved walls nor with complex chromatophores; either non-sexual or isogamous or heterogamous; if with a direct conjugation of walled cells or branches then without chlorophyll.

- (1) Plants with chlorophyll, or if without chlorophyll, then either without a true mycelium, or if a mycelium-like filament is present then with a sexual phase with ciliated, motile spermatozooids and stationary eggs.

- a. Antheridium when present not consisting of a globular structure containing sperm-bearing filaments.

- (a) Plants usually green, with chlorophyll or colorless, nearly all producing nonsexual zoospores; unicellular, colonial, or multicellular, nonsexual or mostly sexual plants, the sexual forms isogamous or heterogamous; nearly all with simple, haploid, sexual cycle, but some apparently with a simple, diploid, sexual cycle.

Phylum IV. GONIDIOPHYTA.

- (b) Plants with the chlorophyll usually hidden by a brown, red, or purple pigment, always with a multicellular body and sexuality.

- ((a)) Mostly marine brown Algae with phycophacin; isogamous or heterogamous with ciliated sperms, both gametes usually discharged from the gametangia; with a simple, diploid, sexual cycle, perhaps some also with a simple, haploid sexual cycle, or in the higher forms with two or more types of the alternation of generations cycle.

Phylum V. PHAEOPHYTA.

- ((b)) Mostly marine red or purple Algae with phyco-erythrin; heterogamous, with stationary eggs and nonciliated sperms; apparently normally with an alteration of generations.

Phylum VI. RHODOPHYTA.

- b. Filamentous, aquatic, green Algae with globular antheridia containing sperm-bearing filaments, the sperms being biciliated; nonsexual spores absent; with a simple, diploid, sexual cycle, the reduction division apparently taking place in the sexual organs.

Phylum VII. CHAROPHYTA.

- (2) Plants without chlorophyll and with a true, septate or nonseptate mycelium; sexual reproduction without motile sperms; nonsexual reproduction of various types; with a simple, haploid, sexual life cycle, or in the higher forms with a modification of this cycle, in which a binucleate or conjugate phase follows the normal haploid phase with uninucleate cells.

Phylum VIII. MYCOPHYTA.

- a. Mycelium cenocytic; without ascospores or basidiospores.

Subphylum 1. PHYCOMYCETAE.

- b. Mycelium normally not cenocytic; with ascospores or basidiospores, or apparently numerous degenerate forms in which such spores are no longer developed, but which are propagated solely by conidia.

Subphylum 2. MYCOMYCETAE.

- II. Plant body a solid aggregate; if filamentous, only so in the embryonic or immature condition; ovary a typical archaegonium or if much reduced then the plants seed-bearing; always with a typical, antithetic alternation of generations in the normal life cycle, the diploid sporophyte being parasitic during its entire life or in its embryonic phase on the gametophyte.

(META-THALLOPHYTA).

- A. Without vascular tissue; sporophyte parasitic on the gametophyte during its entire life and determinate in growth; homosporous; small plants without roots or true leaves.

Phylum IX. BRYOPHYTA.

- B. Always with vascular tissue in the sporophyte which becomes an independent plant, after the embryonic phase, with roots and leaves except in a few degenerate forms; and always with decidedly indeterminate growth of all or part of the axes.

- (A) Sporophyte not seed-producing; sperms breaking out of the antheridium to enter the necks of the archegonia directly; homosporous or heterosporous, the sex being determined either in the gametophyte or in the sporophyte.

1. Spermatozoids comparative large and multiciliate; sporophylls not in cones, or in cones (strobili or primitive flowers), but then the sporophyte with jointed stems and whorled leaves; branching normally monopodial.

- a. Stems not jointed, the leaves usually large and compound and spirally arranged, rarely in whorls, sporophylls never in cones, the reproductive axes always indeterminate.

Phylum X. PTENOPHYTA.

- b. Stems jointed and fluted, bearing whorled leaves, which in living forms and in most fossil forms are much reduced; sporophylls in cones; living species, and many fossil forms also, some with determinate vegetative branches.

Phylum XI. CALAMOPHYTA.

2. Spermatozoids small, biciliate; leaves of the living species small, covering the continuous stem in spirals, or sometimes in opposite arrangement; rarely with a slight internodal development; branching of the stem dichotomous, the lowest species all indeterminate; sporophylls usually in cones or in the lower forms in zones alternating with the sterile leaves; frequently also with determinate vegetative branches; the lowest fossil species with terminal cauline sporangia.

Phylum XII. LEPIDOPHYTA.

(B) Sporophyte producing seeds, the female gametophyte always parasitic in the megasporangium (ovule) during its entire life, the male gametophyte developing a pollen-tube through which the sperms are discharged, hence with a two-phased parasitic growth, the first stage in the microsporangium, the second in the ovule, or in the higher groups beginning in the tissues of the megasporophyll itself (carpel); with a resting stage intercalated between the two phases of the sporophyte; always heterosporous, the sex being determined in the sporophyte.

1. Carpels open, without stigmas or true ovaries, the ovules and seeds naked and the pollen-grains (male gametophytes) falling directly into the micropyle; no true endosperm or xeniophyte present.

a. Sperms so far as known ciliated and motile; ovules with a pollen-chamber; with or without flowers; the sporophylls either being in cones, or in rosettes on indeterminate axes.

Phylum XIII. CYCADOPHYTA.

b. Sperms without cilia; ovules without pollen-chambers; sporophylls in cones, which may be highly specialized or reduced and in the highest types collected into definite inflorescences; woody plants, monocious or diecious.

Phylum XIV. STROBILOPHYTA.

2. Carpels or the set of carpels closed at maturity, with stigmas and with ovaries enclosing the ovules and seeds; pollen-grains falling on the stigma and developing long pollen-tubes; flowers well developed, commonly with a perianth, often highly specialized or reduced; true endosperm or xeniophyte normally present.

Phylum XV. ANTHOPHYTA.

SYNOPSIS OF THE CLASSES AND SUBCLASSES OF THE SEVERAL PHYLA

Phylum, SCHIZOPHYTA. About 2,500 species

I. Cells without chlorophyll, sometimes with bacterio-purpurin; holophytic, saprophytic, or parasitic Fungi.

A. Cells not imbedded in a pseudo-plasmodium; life cycle not with distinct, vegetative and fruiting periods; not forming a myxomycete-like fructification, although the cells may be in gelatinous masses.

SCHIZOMYCETAE. Bacteria.

B. Cells in a pseudo-plasmodium; life cycle with two distinct periods, a vegetative period and a fructification period, when a myxomycete-like fruiting body is developed with or without a stalk.

MYXOSCHIZOMYCETAE. Slime Bacteria.

II. Cells containing chlorophyll and phycocyanin; Algae usually of a blue-green or brownish color.

A. Without a definite nuclear membrane and with a low type of chromatophore.

CYANOPHYCEAE. Blue-green Algae.

B. With nuclear membrane and highly differentiated chromatophores; unicellular or in colonies.

GLAUCOCYSTAE. Higher Blue-green Algae

Phylum, MYXOPHYTA. About 350 species

I. Without zoospores; the cells not fusing into a typical plasmodium; but simply aggregated; spore mass without a covering.

ACRASIAE. Primitive Slime Molds.

II. With zoospores containing a single flagellum; plasmodium of completely fused cells.

MYXOMYCETAE. Slime Molds.

A. Spores developed superficially upon erect branching sporophores, no sporangia being produced.

Subclass, CERATIOMYXAE.

B. Spores developed within a sporangium-like body with a wall, the sporangia distinct or united into an aethalium.

Subclass, MYXOGASTRAE.

Phylum, ZYGOPHYTA. 8,000 species

I. Cell walls impregnated with silica, composed of two valves.

Subphylum and class, DIATOMEAE. Diatoms

II. Cell walls without silica but with abundant development of gelatinous pectose, causing the plants to be slimy to the touch.

Subphylum and class, CONJUGATAE.

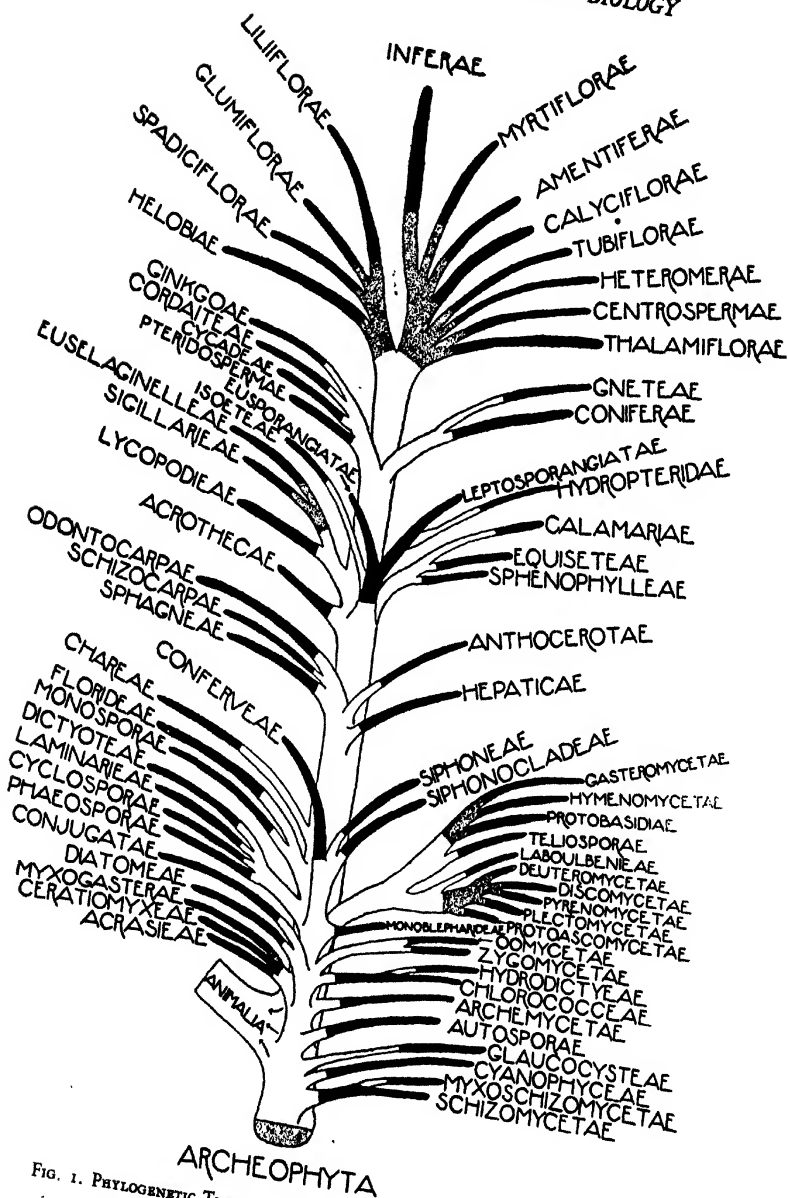


FIG. 1. PHYLOGENETIC TREE OF THE CLASSES AND SUBCLASSES OF PLANTS

Phylum, GONIDIOPHYTA. 2,000 species

I. Plants unicellular or colonial, not truly filamentous.

A. Nonsexual, unicellular or colonial Algae without zoospores, commonly with autospores; cells normally with one nucleus.

AUTOSPORAE. Primitive Green Algae.

- B. Sexual primitive, parasitic or occasionally saprophytic, aquatic or aerial Fungi; or perhaps some nonsexual. ARCHEMYCETAE. Primitive Fungi.
- C. Isogamous or heterogamous, sexual Algae or probable derivatives from them, with zoospores.
 - 1. Unicellular or colonial Algae, usually with one nucleus in each cell, rarely cenocytic, the colonial forms not produced by the symmetrical aggregation of free zoospores; vegetative stage non-motile or active; isogamous or heterogamous. CHLOROCOCCEAE.
 - 2. Algae consisting of colonies of peculiar form, becoming cenocytic, new colonies being produced by the definite arrangement of daughter cells developed in the parent cenocyte; isogamous, aquatic. HYDRODICTYAE.
- II. Green Algae or aquatic Fungi with a filamentous or massive body and 1, 2, 4, or many cilia on the zoospores and gametes.
 - A. Cenocytic; septate or nonseptate, isogamous or heterogamous.
 - 1. Algae usually pure green in color.
 - a. Vegetative body usually septate, consisting of a series of cenocytes; chloroplasts forming a net, rarely in separate plates. SIPHONOCLEAE. Lower Tube Algae.
 - b. Vegetative body usually nonseptate, with distinct, lenticular, oval, or plate-like chloroplasts. SIPHONAE. Higher Tube Algae.
 - 2. Filamentous, saprophytic, aquatic Fungi with stationary eggs and unciliated spermatozooids. MONOBLEPHARIDEAE.
 - B. Algae having normal vegetative cells with one nucleus, with a conjugation of free-swimming gametes, or with motile sperms and stationary eggs. CONFERVEAE. Confervas.

Phylum, PHAEOPHYTA. 1,130 species

- I. Zoospores, when present, and ciliated gametes with two flagella; if with an alternation of generations, then the gametophyte minute.
 - A. Gametangia plurilocular; zoospores produced in unilocular sporangia; apparently without an alternation of generations. PHAEOSPORAE. Little Kelps.
 - B. Gametangia unilocular or unicellular; zoospores none, or when present produced in unilocular sporangia and giving rise to minute male and female gametophytes.
 - 1. With a simple diploid sexual cycle and without zoospores; gametangia unilocular; eggs large and non-motile, but discharged from the oogonium; sperms minute and free-swimming. CYCLOSPORAE. Rockweeds.
 - 2. With an alternation of generations; nonsexual zoospores produced in unilocular sporangia and giving rise to small male and female gametophytes; gametangia unicellular; sporophyte often very large. LAMINARIAE. Giant Kelps.
- II. Nonsexual spores non-motile; sperms with one flagellum; reproductive organs external; with a regular alternation of prominent sexual and nonsexual generations. DICTYOTAE.

Phylum, RHODOPHYTA. 3,100 species

- I. Nonsexual reproduction by single thallus cells, trichogyne imperfectly developed; no pits between the thallus cells. MONOSPORAE.
- II. Nonsexual reproduction by tetraspores usually developed in groups of four; trichogyne well developed; cells protoplasmically connected through large pits in the walls. FLORIDAE.

Phylum, CHAROPHYTA. 160 species

One class, CHARAE. Stoneworts.

Phylum, MYCOPHYTA. About 60,000 species

- I. Plants with cenocytic mycelium, without or with transverse septa.
 - Subphylum, PHYCOMYCETAE. Algal Fungi.
 - A. Sexual spores, "zygospores," produced by the union of the contents of two similar or nearly similar conjugating branches of the mycelium, the one branch not penetrating the other; nonsexual spores rarely zoospores; saprophytes or animal parasites, a few parasitic on other plants. ZYGOMYCETAE.

B. Sexual spores, "oospores," formed by the union of the contents of two conjugating branches of unequal size, the smaller usually penetrating the wall of the larger by means of a fertilization tube; non-sexual spores either zoospores with one or two cilia or conidia; plant or animal parasites or saprophytes, sometimes aquatic. OOMYCETAE.

II. Plants with a septate mycelium, the vegetative cells containing one or two nuclei; normally with a conjugate phase in the life cycle. Subphylum, MYCOMYCETAE. Higher Fungi.

A. With ascospores, commonly 8 in an ascus; conjugate phase present, but usually not prominent. Here are also included all conidial types whose perfect stages are supposed to be ascomycetous.

(A) Asci developed after the conjugation of two cells of the mycelium or parthenogenetically (?); occasionally fertilization by means of detached conidia-like spermatia; nonsexual conidia usually produced; saprophytes or parasites on plants or animals, with an ordinary mycelium; many Lichen-fungi; in many species only the conidial form known. ASCOMYCETAE. Sack Fungi.

1. Ascus stage known, conidial stage also commonly present.

(1) Asci not in a definite fruiting body, with a variable number of spores or with a definite number. Subclass PROTOASCOMYCETAE. Lower Sack Fungi.

(2) Asci with a definite number of spores, in typical cases commonly 4 or 8, the asci collected on or in an ascocarp.

a. Asci arranged at different levels in the fruiting body or fasciculate and surrounded by a spherical, cylindrical, pyriform, or shield-like wall which is commonly perforated at the top, but sometimes completely closed.

(a) Asci arranged at different levels in the fruiting body; or the hymenium lining cavities; mostly mold-like or tuber-like Fungi.

Subclass, PLECTOMYCETAE. Little Tuber Fungi.

(b) Asci in fascicles arising from a common level in a perithecium or cleistothecium or under a shield-like wall; mostly dark-colored Fungi.

Subclass, PYRENAMEYCETAE. Black Fungi.

b. Asci collected in a flattened, concave, convex, or irregular hymenial layer or the asci permanently enclosed; fruiting body (ascoma) a disk-like or cup-like apothecium or at first closed and opening at maturity, the hymenial layer sometimes becoming pulverulent; sometimes prominently stalked. Subclass, DISCOMYCETAE. Disk Fungi.

2. Ascus stage not known, the hyphae bearing conidia only, also isolated conidial stages whose asci are known; imperfect Fungi with the conidia superficial or in pycnidia, borne on loose innate hyphae. A provisional subclass for conidial forms with uninucleate cells.

Subclass, DEUTEROMYCETAE. Imperfect Fungi.

(B) Asci developed after fertilization by means of a trichogyne and spermatium, no conidia known, but the spermatia sometimes conidium-like; minute Fungi with a peculiar vegetative body parasitic on various insects, especially water beetles. LABOULBENIACEAE. Beetle Fungi.

B. With basidiospores, commonly 4, developed on a basidium, one prominent stage of the mycelium with two nuclei in each cell (conjugate phase) and with clamp connections in some groups; conidia sometimes produced, or spores of various types.

1. Basidia arising from teliospores; often other types of spores also produced; plant parasites, often heterecious; conjugate phase often prominently developed. TELIOSPORAE. Brand Fungi.

2. Basidia produced directly on the vegetative mycelium, no proper teliospores being present, mostly saprophytes, but some parasitic, especially on trees; often with massive and very complex fruiting bodies; conjugate phase prominently developed, with clamp-connections; terrestrial or epixylous; a few Lichen-Fungi. Here are included the most if not all of the sterile mycelia known as mycorrhiza. BASIDIOMYCETAE. Basidium Fungi.

a. Basidia septate transversely or longitudinally, or sometimes merely deeply two-forked; fruiting body mostly gelatinous; saprophytes. Subclass, PROTOBASIDIACE.

b. Basidia nonseptate.

(a) Basidia on a distinct, membranous hymenium exposed from the beginning or at first covered but finally naked, covering gills, pores, spines, or a smooth or wrinkled surface; rarely parasitic and without a special fruiting body, the basidia then arising out of the epidermis of the host plant. Subclass, HYMENOMYCETAE.

- (b) Basidia enclosed within a definite peridium but sometimes exposed at maturity, the spores then borne in a more or less deliquescent gleba. Subclass, *GASTEROMYCETAE*.

Phylum, *BRYOPHYTA*. 17,000 species

- I. Gametophyte with gametangia not imbedded in the thallus tissue; sporophyte not with intercalary growth between the sporangium and foot; sporangium not two-valved when a central columella is present.
 - A. Rhizoids unicellular; mature gametophyte thalloid or a stem-like frond with scales; sporangium without a central columella, without or with elaters. *HEPATICAE*. Liverworts.
 - B. Rhizoids multicellular or septate; mature gametophyte not thalloid; nearly always stem-like and covered with scales; sporangium nearly always with a central columella, if not, then without elaters.
 1. Gametophyte with a pseudopodium bearing the mature sporophyte; sporangium not with a complete columella, but with a dome-shaped cavity.
 - a. Gametophyte gray-green, with two kinds of cells in the scales, narrow ones with chlorophyll and large ones without, but commonly with spiral fibril bands; sporangium with an operculum. *SPHAGNEAE*. Bog Mosses.
 - b. Gametophyte dark colored, not with two distinct kinds of cells in the scales; sporangium splitting into 4 or more valves. *SCHIZOCARPAE*. Granite Mosses.
 2. Gametophyte without a pseudopodium; sporangium nearly always with a complete columella, usually with an operculum and a well-developed peristome of teeth. *ODONTOCARPAE*. Mosses.
- II. Venter of the archegonium sunken in the body of the gametophyte; rhizoids unicellular; sporophyte with prominent intercalary growth between the sporangium and foot; sporangium two-valved, with a central columella. *ANTHOCEROTAE*. Hornworts.

Phylum, *PTENOPHYTA*. 7,000 species

- I. Sporophyte homosporous; gametophyte usually comparatively large and mostly hermaphroditic except in extreme forms.
 - A. Sporangia eusporangiate in origin. *PHYLOPTERIDAE*. Ferns.
 - B. Sporangia leptosporangiate in origin. Subclass, *EUSPORANGIATAE*.
- II. Sporophyte heterosporous; gametophytes minute, unisexual; leaves not with ligules; sporangia in sori inclosed in a modified leaflet (sporocarp) or in modified indusia; leptosporangiate. *HYDROPTERIDAE*. Water Ferns.
- III. Sporophyte heterosporous; gametophytes minute, unisexual; leaves with ligules and with sporangia borne singly, imbedded on the upper side near the base; eusporangiate. *ISOETAE*. Quillworts.

Phylum, *CALAMOPHYTA*. 23 living species

- I. Sporophyte homosporous; gametophytes hermaphroditic or the highest somewhat unisexual.
 - A. Leaves not fused into a sheath; sporangia stalked on the upper side of the sporophyll; stem with a central, triarch vascular bundle; paleozoic fossils. *SPHENOPHYLLAE*.
 - B. Leaves united into a sheath with teeth; sporophylls shield-shaped, with sack-like sporangia on the inner side; stem with a ring of vascular bundles and a central pith which is usually hollow, some fossil forms with secondary thickening. *EQUISETAE*. Horsetails.
- II. Sporophyte somewhat heterosporous; gametophytes unisexual; paleozoic fossils. *CALAMARIAE*.

Phylum, *LEPIDOPHYTA*. 800 living species

- I. Sporophyte homosporous; leaves when present without a ligule; gametophytes usually hermaphroditic.
 - A. Sporangia large, terminal, cauline structures; Devonian fossils. *ACROTHECAE*.
 - B. Sporangia on sporophylls or in the axils of leaves. *LYCOPODIAE*. Lycopods.
- II. Sporophyte heterosporous; leaves with a ligule, gametophytes unisexual, small. *SELAGINELLEAE*. Selaginellas.
 - A. With increase in thickness of stem by means of a cambium; paleozoic fossil trees. Subclass, *SIGILLARIAE*.
 - B. Without increase in thickness of stem; present day herbs. Subclass, *EUSELAGINELLEAE*.

Phylum, CYCADOPHYTA. 90 living species

- I. Leaves usually compound; stem an unbranched shaft or with few branches.
 - A. Megasporophylls only moderately or slightly differentiated from the foliage leaves; leaves fern-like, often very much compounded; no cones known; paleozoic fossils. PTERIDOSPERMAE.
 - B. Megasporophylls (carpels) highly specialized, usually very different from the foliage leaves; at least one kind of sporophylls in cones, the cones bisporangiate or monosporangiate; some living and numerous fossil forms. CYCADEAE. Cycads.
- II. Leaves usually simple or lobed; venation dichotomous or parallel; stems with several or numerous branches forming a crown.
 - A. Without dwarf branches; leaves usually elongated with parallel veins; fossil trees. CORDAITAE.
 - B. With thick wart-like dwarf branches and ordinary branches having well-developed internodes: leaves fan-shaped, dichotomously veined, sporophylls not in cones, the plant entirely flowerless, all fossil except one surviving living species. GINKGOAE. Maiden-hair-trees.

Phylum STROBILOPHYTA. 400 living species

- I. No vessels (enlarged tracheids) in the secondary wood; wood frequently with resin ducts or cells; leaves mostly spiral, sometimes opposite or whorled; cotyledons 2-15. CONIFERAE. Conifers.
- II. Vessels present in the secondary wood, wood without resin ducts; embryo with 2 cotyledons; reduced flowers in specialized inflorescences; leaves opposite or in threes. GNETAE. Joint-firs.

Phylum, ANTHOPHYTA. 150,000 species

- I. Stems with closed, usually scattered vascular bundles; embryo usually with one terminal cotyledon and a lateral plumule; flowers mostly in threes, all except the lowest types being of the pentacyclic trimerous condition or a modification of this; leaves commonly three-spiral in the lower types and two-ranked in the higher. MONOCOTYLAE. Monocotyls.
 - A. Flowers with many to few free carpels, or the carpels united, in which case they are numerous, or if three, two, or apparently one, then the flowers in a spadix, usually with a spathe, or the leaves segmented and fan-like or featherlike; a few with reduced flowers in glomerules and a few aquatic plants extremely modified and without a perianth.
 1. Aquatic or mud plants, or rarely non-green phagophytes, with primitive or highly specialized flowers, but not in a typical spadix or dense glomerules; hypogynous or epigynous herbs. Subclass, HELOBIAE.
 2. Usually terrestrial plants but sometimes aquatic; trees, shrubs or herbs with segmented leaf-blades, or plants with the flowers in spadixes or dense glomerules, usually with spathes; or minute, free-floating plants without leaves and with extremely reduced flowers; hypogynous; choripetalous, sympetalous, or apetalous. Subclass, SPADICIFLORAE.
 - B. Flowers with united carpels, normally pentacyclic and trimerous or a modification or reduction of this type, often covered with glumes and then having a vestigial perianth or none whatever; if trees with pentacyclic trimerous flowers then not in spadixes and the leaf blade not segmented.
 1. Flowers usually reduced, always hypogynous, in spikelets covered with glumes, the ovary nearly always unilocular; leaves narrow and usually elongated; usually with one or all the internodes elongated. Subclass, GLUMIFLORAE.
 2. Flowers mostly showy and normally pentacyclic, or of a somewhat modified pentacyclic, trimerous type, rarely covered with glume-like structures, hypogynous or epigynous; trees, shrubs, vines, and herbs of many types. Subclass, LILIIFLORAE.
- II. Stems with open vascular bundles usually in a circle, with a cambium cylinder; embryo usually with two cotyledons and a terminal plumule; flowers mostly pentamerous or tetramerous, of many diverse types from low to high, occasionally trimerous; plants of many diverse habits, trees, shrubs, lianas, perennial and annual herbs, and other forms. DICOTYLAE. Dicotyls.
 - A. Mostly with hypogynous flowers, occasionally epigynous.
 1. Mostly choripetalous or apetalous, occasionally sympetalous.
 - a. Mostly choripetalous and mostly not with central placentation when the carpels are united. Subclass, THALAMIFLORAE.
 - b. Typically apetalous, but some choripetalous or sympetalous; mostly with central or basal placentation. Subclass, CENTROSPERMAE.

2. Mostly sympetalous, occasionally choripetalous or apetalous.
 - a. Flowers pentacyclic or sometimes a reduction from this condition; carpels mostly 5. Subclass, HETEROMERAE.
 - b. Flowers tetracyclic or less; carpels mostly 2, occasionally 3. Subclass, TUBIFLORAE.
- B. Mostly with perigynous or epigynous flowers or with a reduced or primitive perigynous condition.
 1. Mostly perigynous or a reduction from this condition, occasionally epigynous; mostly choripetalous or apetalous.
 - a. Petals commonly present; flowers usually not in ament-like clusters, hypanthium mostly prominent. Subclass, CALYCIFLORAE.
 - b. Mostly apetalous; flowers, at least the staminate ones, commonly in aments or ament-like clusters; hypanthium mostly inconspicuous or reduced. Subclass, AMENTIFERAE.
 2. Epigynous, with or without a hypanthium; mostly choripetalous or sympetalous, occasionally apetalous.
 - a. Flowers mostly choripetalous and not in umbels; epigynous hypanthium frequent. Subclass, MYRTIFLORAE.
 - b. Flowers typically sympetalous, the choripetalous groups mostly with umbels; epigynous hypanthium rare; calyx often reduced, or replaced by a specialized pappus; flowers frequently in disks or heads. Subclass, INFERAE

THE SEGREGATIVE AND PROGRESSIVE MOVEMENTS IN THE ANTHOPHYTA

The segregation of the Anthophyta into classes and subclasses has been given above and, since the flowering plants are not only the highest but also the most numerous in species and by far the most important economically, the treatment is here continued to the orders and the general phylogenetic arrangement is presented in figure 2. Since the flower is a determinate, sporophyll-bearing shoot and since there is a consistent evolution of promptness and definiteness of the determinateness of the floral axis in all the phyletic lines which evolve flowers, the results are very evident and give rise to the following general, progressive conditions: 1. Hypogynous apocarpous spiral; 2. Hypogynous apocarpous cyclic; 3. Hypogynous syncarpous plurilocular; 4. Hypogynous syncarpous unilocular; 5. Epigynous plurilocular; 6. Epigynous unilocular. These stages represent the consistent orthogenetic evolution which has resulted in the present system of flowers. As intimated the evolutionary series is dependent on the promptness of the determination of the flower axis in relation to the time of appearance of the reproductive

reactions. All the lower types of flowers as represented in *Equisetum*, Lycopods, Selaginellas, Cycads, and Araucarians have spiral flowers with many free sporophylls, and in the Anthophyta the lowest types are represented by quite similar, hypogynous, spiral, apocarpous flowers, as in *Echinodorus*, *Sagittaria*, *Magnolia*, and *Ranunculus*.

Since the primitive Angiospermous flower has a regular sequence in the development of secondary sexual states, various hereditary potentialities may evolve which have an expansive effect on the floral axis in relation to the male or female state, or in some cases to both states. Thus there result finally eight fundamental, structural types of flowers, due to the evolution of the shortening of the axis and the expansions in relation to particular sexual states. Some of these types are evolved in most of the phyletic lines, which makes definition of the various subgroups very difficult. There is also an evolutionary progression from the bisporangiate flower condition through various stages and degrees of monociousness and dieciousness. These evolutionary movements are especially responsible for many of the vestigial stamens and

carpels present in monosporangiate flowers. In many of the higher phyletic lines and occasionally in lower ones zygomorphy is evolved, which is also responsible for very definite orthogenetic series and the progressive development of vestiges and loss of parts in the flower.

When it comes to the direct question as to which of the two classes of Angiosperms represents the more primitive condition, the answer is that in some respects the Monocotyls are the more primitive and in some respects the Dicotyls. The Monocotyls have apparently in their more generalized forms preserved the primitive tree type with little branching ability, as in Palms, Dracaenas, Yuccas, Fourcroyas, and Ravenalas. The tree Ferns, and Cycads have this general form of plant body, and from this type the trees with crowns of small branches, like Ginkgoes, Araucarias, and Magnolias, have probably been derived. The Monocotyl embryo with its single terminal embryonic leaf (cotyledon) is nearer the primitive fern embryo than the Dicotyl type. The Dicotyl embryo evolved in the Cycads, lower Conifers, Gnetums, and Dicotyls. On the other hand, the ring of open vascular bundles of the Cycads, Conifers and Dicotyls is apparently a direct descendant of the vascular system of the lower Eusporangiate Ferns.

The lowest flower types among the Monocotyls are found among the Alismataceae, Cabombaceae and the lower Palmaeae, while the lowest Dicotyl flowers are present in Magnoliaceae, Ranunculaceae, and Rosaceae. Culmination types in the Monocotyls are represented by such genera as *Zostera*, *Vallisneria*, *Typha*, *Zea*, *Eriocaulon*, and *Corallorrhiza*, and in the Dicotyls by *Viola*, *Monolepis*, *Casuarina*, *Quercus*, *Salix*, *Hippuris*, *Salvia*, *Ambrosia*, and *Leontodon*.

In the Angiosperms, bisporangiate, entomophilous flowers represent the primitive condition, from which the extreme types of entomophilous, anemophilous and hydrophilous flowers were evolved. In some of the more advanced or extreme forms, both in the entomophilous and anemophilous series, self-pollination, cleistogamy, and parthenogenesis were then evolved as extreme conditions. The lower types of flowers are usually conspicuous because of their size, while the highest are often very inconspicuous because of reduction and crowding in the evolved inflorescence, and the loss of the corolla. This may, however, be compensated by the massing of the minute flowers or the development of conspicuous involucre around the inflorescence. The apetalous Angiosperms are not primitive as suggested in the taxonomic systems of Engler and Wettstein. They are practically all reduced and syncarpous and have extremely reduced and specialized floral axes. This topsy-turvy sequence of the Angiospermous series has been a fertile source in the perpetuation of fundamentally wrong notions in regard to the evolutionary process and the causes through which evolution operates. There are several ways of determining comparative levels of development as low or high, besides the fundamental method of making a catalogue of important potentialities. The degree of divergence in structure and function of homologous parts is usually a good guide, as for example, the number of diverse expressions of the same organ, as the number of types of leaves, the number of types of stems on the individual, the degree of divergence between the general vegetative axis and the floral axis or its peduncle, and the degree of divergence between sporophylls and foliage leaves.

BRIEF SYNOPSES OF THE ORDERS OF THE SUBCLASSES OF ANTHOPHYTA

HELOBLIAE

- I. Flowers hypogynous or somewhat perigynous, or a few epigynous; carpels free or united, spiral or cyclic.
 - A. Plants normal, with chlorophyll.
 - 1. Hypocotylary expansion, if present, not lobed or only slightly notched; ovules usually anatropous or campylotropous; leaves often narrow, if broad, not peltate and not with a narrow basal sinus but sometimes sagittate or deeply cordate; flowers hypogynous. *Alismatales.*
 - 2. Hypocotylary expansion parted into two lobes or deeply notched; ovules orthotropous; aerial or floating leaves peltate or with a deep basal sinus, or if somewhat sagittate then the carpels numerous and united; hypogynous to epigynous. *Nymphaeales.*
 - B. Small yellowish or reddish phagophytes without chlorophyll; tropical forest plants. *Triuridales.*
- II. Flowers epigynous; carpels united, cyclic; leaves not peltate nor with a deep sinus. *Hydrocharitales.*

SPADICIFLORAE

- I. Inflorescence not a typical spadix except in the higher forms; leaves frequently plicate and more or less split at maturity.
 - A. Leaves usually plicate and more or less split.
 - 1. Carpels free or united, usually 3, forming a unilocular or plurilocular ovary with one ovule for each carpel. *Palmates.*
 - 2. Carpels united; ovary unilocular with numerous seeds on 2 or 4 parietal placentae. *Cyclanthales.*
 - B. Leaves linear or sword-shaped, not plicate and not splitting at maturity; flowers monocious, spicate or capitate. *Pandanales.*
- II. Inflorescence usually a fleshy spadix with or without a spathe; or minute plants without leaves, floating free, the flowers few or solitary on the modified stem. *Arales.*

GLUMIFLORAE

- I. Ovary trilocular to unilocular; ovules solitary in the cavities, orthotropous, pendulous. *Restionales.*
- II. Ovary unilocular, one-ovuled; ovules anatropous, erect or ascending. *Graminales.*

LILIIFLORAE

- I. Flowers hypogynous; seeds with endosperm. *Liliales.*
- II. Flowers partly or completely epigynous.
 - A. Seeds with endosperm.
 - 1. Flowers mostly actinomorphic or slightly zygomorphic. *Iridales.*
 - 2. Flowers zygomorphic or very irregular. *Scitaminales.*
 - B. Seeds without apparent endosperm, very numerous and usually minute; flowers mostly zygomorphic, a few of the lowest actinomorphic. *Orchidales.*

THALAMIFLORAE

- I. Carpels many to one, spiral or cyclic, usually free or only slightly united; stamens usually numerous. *Ranales.*
- II. Carpels usually more or less united, cyclic.
 - A. Herbs with insectivorous leaves; carpels 6-3. *Sarraceniales.*
 - B. Herbs or woody plants with normal leaves, not insectivorous.
 - 1. Carpels 2 or more, with parietal placentae, perianth, usually with an even number of segments, the flowers commonly partially or completely isobilateral. *Brassicales.*
 - 2. Carpels mostly 5 or 3; stamens mostly 10 or 5, or a reduction from 10, ovules mostly pendulous; flowers commonly of the hexacyclic type with one or more cycles represented by glands, or a reduction of this type. *Geraniales.*
 - 3. Carpels many to 3, ovules few; stamens indefinite, monadelphous, branched or clustered, or by reduction separate and few; sepals valvate. *Malvales.*
 - 4. Carpels 2 or more, commonly with parietal placentae; stamens numerous to few; sepals and petals usually 5, sepals imbricated or convolute. *Violales.*

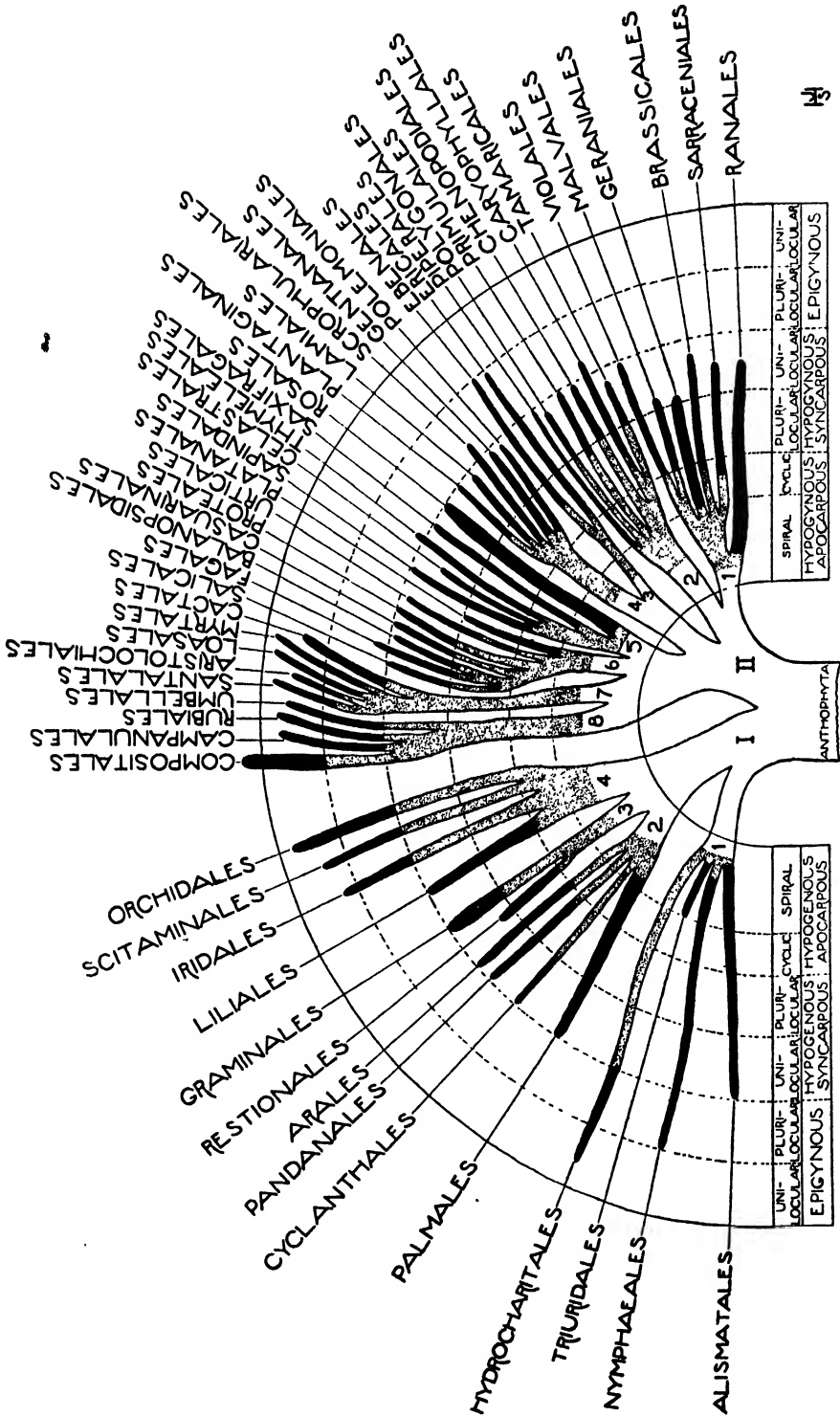


FIG. 2. PHYLOGENETIC BRANCH OF THE ORDERS OF ANTHOPHYTA

CENTROSPERMAL

- I. Perianth present, consisting of a calyx and corolla, or of a calyx only.
 - A. Fruit not an achene or rarely so.
 - 1. Corolla usually choripetalous or none.
 - a. Embryo straight; fruit a capsule. *Tamaricales.*
 - b. Embryo curved, coiled or annular.
 - (a) Fruit a capsule, berry, or anthocarp; calyx present; corolla present or absent. *Caryophyllales.*
 - (b) Fruit a utricle; calyx present; corolla usually none. *Chenopodiales.*
 - 2. Corolla mostly sympetalous; fruit fleshy, or a dry capsule, utricle, or achene. *Primulales.*
 - B. Fruit an achene; embryo straight or nearly so; stipules commonly ocreae. *Polygonales.*
- II. Perianth none or vestigial; ovules usually orthotropous. *Piperales.*

HETEROMERAE

- I. Stamens mostly free from the corolla, alternate with its lobes or twice as many; seeds usually minute. flowers mostly bisporangiate, hypogynous or epigynous, sometimes choripetalous. *Ericales.*
- II. Stamens united with the corolla and opposite its lobes or twice as many or more; seeds usually one or few in the cavities, usually large; flowers hypogynous or sometimes epigynous, sometimes choripetalous; *Ebenales.*

TUBIFLORAE

- I. Corolla not scarious, nerved.
 - A. Fruit usually a capsule, berry, drupe, or samara; carpels commonly several- to many-seeded.
 - 1. Corolla regular; stamens usually of the same number as the corolla lobes.
 - a. Leaves alternate or opposite; ovaries not separating; carpels 3 or 2. *Polemoniales.*
 - b. Leaves usually opposite; ovaries frequently separating below, with a common style; if not separating then usually with 2 cavities or 2 placentae. *Gentianales.*
 - 2. Corolla mostly irregular or oblique, the flowers zygomorphic, fertile stamens commonly fewer than the corolla lobes except in the lower species. *Scrophulariales.*
 - B. Fruit indehiscent but usually splitting and forming 4 nutlets around the style, rarely fleshy; carpels 1-2-seeded. *Lamiales.*
- II. Corolla usually scarious, nerveless; calyx and corolla 4-lobed. *Plantaginales.*

CALYCIFLORAE

- I. Carpels free or united, spiral or cyclic.
 - A. Endosperm usually little or none; leaves mostly with stipules; carpels spiral or cyclic, often reduced to one, usually free or only slightly united, with a few evident exceptions. *Rosales.*
 - B. Endosperm present and usually copious; leaves usually without stipules; carpels cyclic, free or united, sometimes slightly epigynous. *Saxifragales.*
- II. Carpels united, cyclic.
 - A. Hypanthium tubular or urn-shaped, often constricted above and enclosing the ripe fruit; endosperm commonly little or none. *Thymelaeales.*
 - B. Receptacle developing a glandular, annular, or turgid disk which is somewhat united with the perianth or ovulary; endosperm present or none. *Celastrales.*
 - C. Disk tumid, united with the perianth, sometimes reduced; endosperm usually none. *Sapindales.*

AMENTIFERAE

- I. Flowers not in typical aments, often in pendent heads or ament-like spikes or clusters, usually monosporangiate.
 - A. Leaves alternate or rarely opposite.
 - 1. Stamens alternate with the petals (when present) or numerous; perianth sometimes none. *Platanales.*
 - 2. Stamens commonly 4, opposite the usually 4 sepals.
 - a. Calyx not petaloid. *Urticales.*
 - b. Calyx petaloid; stamens usually united with the sepals. *Proteales.*
 - B. Leaves whorled, reduced to scales; ovulary unilocular, with 2 ovules. *Casuarinales.*

II. Flowers, at least the staminate ones, in aments; monosporangiate.

- A. Seeds not with a tuft of hairs; fruit a typical or modified nut; achene, or samara; plants monocious or diecious.
 - 1. Fruit two- or several-seeded; ovules with one integument; diecious trees or shrubs. *Balanopsidales.*
 - 2. Fruit usually one-seeded; monocious or diecious trees or shrubs. *Fagales.*
- B. Seeds with a tuft of hairs at one end, several in the capsule; flowers normally diecious, without perianth; trees or shrubs usually with alternate leaves. *Salicales.*

MYRTIFLORAE

- I. Petals usually numerous, rarely wanting; mostly fleshy, usually prickly and spiny plants with jointed stems and reduced leaves, or the stems not jointed but the leaves fleshy. *Cactales.*
- II. Petals usually not more than 5 or 6 or often none; trees, shrubs, or herbs not spiny like the preceding; calyx segments rarely more than 5 or 6.
 - A. Petals usually present, choripetalous, sometimes sympetalous or apetalous.
 - 1. Flowers mostly bisporangiate; placentae usually axile or apical, rarely basal or parietal. *Myrtales.*
 - 2. Flowers bisporangiate or monosporangiate; placentae usually parietal; mostly herbs or herbaceous vines. *Loasales.*
 - B. Petals usually absent, if present either choripetalous or sympetalous.
 - 1. Ovary usually with several cavities, usually 6; herbs or vines, sometimes parasitic. *Aristolochiales.*
 - 2. Ovary unilocular; mostly parasitic shrubs or herbs. *Santalales.*

INFERRAE

- I. Anthers separate; trees, shrubs, or herbs.
 - A. Corolla choripetalous; flowers usually in umbels or cymes. *Umbellales.*
 - B. Corolla sympetalous, leaves opposite or verticillate. *Rubiales.*
- II. Anthers with few exceptions united; corolla sympetalous, sometimes absent, mostly herbs, rarely shrubs or trees.
 - A. Flowers not in involucre heads. *Campanulales.*
 - B. Flowers in dense involucre heads; gynecium of 2 or rarely 3 united carpels, unilocular; seed one. *Compositales.*

THE DIRECT CUMULATIVE SERIES OF POTENTIALITIES FROM THE BACTERIA TO THE DANDELION

An inspection of the two phyletic "trees" will indicate that the Compositales have attained the highest position in the plant kingdom and in a study of this order it becomes evident that the common Dandelion (*Leontodon taraxacum* L. or *Taraxacum officinale* Weber.) belongs to the very highest type. Its direct phylogenetic history can then be reconstructed in a general way by making a summation of all the fundamental and important potentialities accumulated by its protoplast during its long evolutionary history. It will be noted that few if

any of these potentialities are of the nature of the genes or unit factors with which the present science of genetics is mainly concerned. These fundamental potentialities are not added in a haphazard way, nor have they been subject to loss, at least in the surviving groups, during geological history. Genetics as at present developed and practiced is, therefore, of very little value in the more fundamental aspects of taxonomy and evolution. Its chief value at present is as an aid in the study of varieties within the species and the influence and results of hybridization between related species. With all the known mutations and hybridizations in the closely related group of *Oenothera* species, we still have an

ordinary Evening Primrose; with all the known mutations and hybridizations of *Drosophila*, we still have the little Fruit Fly. We have not made any definite progress toward an understanding of how these organisms acquired their complex complement of fundamental, progressive and digressive potentialities which determine their comparative level in the general biological scale or their relation in a certain phylum, class, order, and family. The most important fundamental hereditary properties of the Dandelion are as follows:

1. With the genesis of living things or bionts there came into existence autogens possessing the power of assimilation or self-perpetuation.

2. The potentiality of self-division, with the two daughter particles retaining all the original potentialities.

3. The power of mutation, through which from time to time an individual autogen is changed to a new pattern with new potentialities.

4. Autogens of two or more kinds with the power of correlative interaction and a number of these ultimate living units held together in a unitary reaction field.

5. The simplest unicellular condition consisting of a definitely organized reaction system or protoplast. Practically all organisms up to the highest plants and animals exist as separate cells in one or more stages of their life cycle.

6. The ordinary physiological properties or potentialities as absorption, respiration, mobility, etc.

7. Division of the organized protoplasmic units or protoplasts and their cell organs, resulting in a perpetuation of the complex system as a whole after division.

8. Property or potentiality to deposit cellulose, etc. in or on the cell wall.

9. The introduction of a more complex

system of the protoplasm with highly organized nucleus, with nuclear membrane, chromosomes, etc.

10. Development of a chloroplast with chlorophyll.

11. Potentiality for karyokinesis of the higher type during cell division; with formation of a special cell wall between the daughter cells and final separation.

12. Process of photosynthesis with the usual formation of sugar, starch, etc., which is not lost in the main series.

13. Potentiality of sexuality with appearance of primary sexual states giving the property of attraction and fusion between isogamous gametes, the cells from time to time being in any of the three states,—female, male, neuter.

14. The reduction division phase with synapsis of chromosomes. The sequences of reduction, fertilization, and the individual give rise to various types of life cycles. (There is a partial inhibition of synapsis in the Dandelion.)

15. Mendelian heredity as a result of fertilization and meiosis and exhibition of dominance and recessiveness in the diploid phase. (Because of diploid parthenogenesis, no segregation of Mendelian factors usually takes place in the Dandelion.)

16. Multicellular condition, at first colonial, and a restriction of separation of cells; in the main series developing a linear aggregate.

17. Attainment of heterogamy.

18. Normal, higher type of heterogamy with extremely dimorphic gametes.

19. Differentiation system depending on physiological gradients in the multicellular body and a complexity of major and minor hereditary potentialities, not all of which are expressed at a given time or in a given cell.

20. Secondary sexual states in the gametophyte.

21. Retention of the egg in the ovary.
22. Progression from a linear aggregate to a solid aggregate, the filamentous condition being confined to the juvenile phase of the gametophyte. In the higher plants the filamentous condition is eliminated.
23. Evolution of an epidermis and distinct internal tissues.
24. Typical antithetic alternation of generations life cycle established with the twelve antithetic stages.
25. Completely parasitic, enclosed sporophyte.
26. Two-phased sporophyte, the juvenile enclosed and the mature exposed condition.
27. Transpiration established in the sporophyte, with stomata.
28. Two-phased sporophyte with parasitic and completely independent phases.
29. Indeterminate growth of sporophyte; reproduction not followed by immediate death.
30. Negative geotropism of the stem bud.
31. Central vascular strand evolved. This is shown in the embryo of the higher plants as the plerome.
32. Sinking of the archegonium venter into the tissues of the gametophyte.
33. The normal vascular system, in the main line with pith on the inside and cortex on the outside.
34. Highly evolved cambium system with secondary growth in thickness.
35. Production of lateral stem appendages or leaves.
36. Roots, originating at first as lateral organs and later as basal organs of the embryo.
37. Geotropism of roots.
38. Spiral arrangement of the lateral appendages or leaves.
39. Phototropism and decided dorsiventrality of the leaves.
40. Shifting of spore production to the leaves.
41. Monopodial branching of the sporophyte and axillary bud development.
42. Dimorphism between sporophylls and foliage leaves.
43. Shifting of time of sex determination from the gametophyte to the sporophyte.
44. In consequence of secondary sexual states in the sporophyte, dimorphic sporangia and spores produced, microspores and megaspores.
45. Unisexual gametophytes.
46. Decided reduction in size of gametophytes, namely more prompt determination.
47. Determinate reproductive axis of the sporophyte or flower potentiality.
48. Megaspore and microspore retained and germinating in the sporangia.
49. In consequence of spore retention, parasitic gametophytes.
50. Pollination process established.
51. Acquisition of a two-phased male gametophyte with development of the parasitic pollen tube.
52. Ovules or megasporangia with integuments.
53. Resting stage of embryo intercalated between the parasitic and independent phases of the sporophyte, resulting in seed dormancy.
54. Abscission of fruit or seed.
55. Sprouting of seed with complex reactions added at this phase.
56. Development of peduncle below flower.
57. Extreme differentiation of tissues of carpel and stamen from leaf tissue.
58. Closing of the carpellate leaf, producing an ovary.
59. Development of a stigma.
60. Limitation of the growth of the gametophytes to an 8-celled female and a 3-celled male condition.

61. Preparation for triple fusion. (This is not completed in the Dandelion because of interference of new factors in the sexualization process.)

62. Triploid endosperm or xeniophyte. (Absent in Dandelion, because of failure of triple fusion.)

63. Perianth developed.

64. Change from spiral to cyclic condition of floral parts.

65. Anatroplus condition of ovule from original orthotropous condition which is still repeated in the ontogeny.

66. Branching in the reproductive axis, causing an inflorescence.

67. Internodal development in sporophyte.

68. Establishment of a pentamerous condition in the flower.

69. Introduction of dicotyledonous embryo type.

70. Change to netted-veined condition of leaf from the original dichotomous condition.

71. United carpels, only the stigmas distinct.

72. Advanced determinate condition of the floral axis resulting in epigyny.

73. Sympetalous condition, from free petals, still represented by the vestigial corolla lobes.

74. Stamen characters very extreme, the anthers sagittate.

75. Union of stamen filaments with the corolla.

76. United anthers or synantherous condition.

77. Zygomorphy of corolla with split strap-shaped condition.

78. Change in internodal development, resulting in one elongated internode or scape which in favorable conditions may be over 2 feet long.

79. Rosette condition of leaves.

80. Disk or head evolved, or extremely determinate inflorescence axis.

81. Special bracts of the involucre.

82. Suppression of the leaf bracts subtending the individual flowers.

83. Unilocular ovary with one seed.

84. Reduction of stigmas to two.

85. Coiling of stigmas.

86. Pappus development, replacing the calyx.

87. Greatly reduced flower and pedicel.

88. Development of complex leaf reaction during the ontogeny.

89. Lactiferous vessels.

90. Secretion of latex with bitter principle.

91. Hollow peduncle.

92. Hollow petiole.

93. Special root segmentation property.

94. Special reproductive property of roots.

95. Development of parachute neck at top of achene.

96. Interference with complete sexualization of chromosomes, inducing imperfect synapsis at reduction.

97. Diploid female gametophyte and parthenogenetic development of the diploid egg.

98. Interference with Mendelian hereditary transmission because of parthenogenesis.

99. Special ribs and projections on the achene.

100. Reflexing of the involucre bracts.

101. Closing of flower heads in the dark and in low temperatures.

These potentialities are all stowed away somewhere in the structure and pattern of the individual protoplast of the Dandelion. The characteristics enumerated are, of course, not always given in the order of their probable evolution but with intensive study even the approximately correct order might be discovered. It will be noted that only a few of the later potentialities are of such a nature that they might possibly be dependent on unit

genes for the characters developed. The unit gene system is apparently entirely inadequate to serve as a basis for fundamental taxonomic speculations beyond the consideration of the special varietal and specific characters, all of which can be changed without affecting the general taxonomic basis of the species or group in question. These fundamental potentialities may be due to a very complex pattern of autogens which when once evolved is never lost. They certainly cannot be due to unit genes having a definite position in a certain chromosome; otherwise we would have to assume a stability to the chromosome mechanism entirely contrary to the observed facts of chromosome behavior.

PHYLOGENETIC SERIES FROM BACTERIA TO INDIAN CORN

Indian Corn (*Zea mays* L.) represents a culmination type in the Glumiflorae of the Monocotylae. It has, like many other culmination types, a number of very extreme and bizarre characters. In the old classifications still in use the grass series has been completely topsy-turvy and in consequence taxonomists, evolutionists, and geneticists have developed entirely false conceptions and principles in relation to this most important group of plants. The lowest grasses are the bamboos with large, fleshy fruits and the highest are such types as Teosinte and Indian Corn. The first 67 fundamental potentialities enumerated above for the Dandelion are also contained in the protoplast of Indian Corn, except that there is no interference with the normal sexual processes. Continuing the series along the phylogenetic line of *Zea*, the accumulation of fundamental, progressive and segregative potentialities will be as follows:

68. Evolution of a closed, scattered

vascular bundle system. This may have occurred quite early in the phylogeny of the Monocotylae.

69. Evolution of the trimerous, pentacyclic flower type.

70. Change to a characteristic, parallel-veined leaf from the dichotomous type.

71. Development of a prominent leaf sheath.

72. Union of the three carpels in the flower.

73. Change from the 3-spiral to the 2-ranked vegetative leaf condition.

74. Development of a characteristic spikelet in the inflorescence.

Beginning of the Grass Series with Bamboos, Like Ochlandra or Melocanna

75. Loss of the outer perianth cycle. The condition of the perianth in the lower groups of the Sedge Family indicates that the original grass perianth was dicyclic.

76. Addition of a contraction potentiality active in the base of the flower, resulting in a two-keeled palet.

77. Definite establishment in the grass series of 6 stamens in the flower and 3 definite lodicules (inner perianth segments), resulting in a tetracyclic flower.

78. Potentiality for a unilocular ovulary.

79. Evolution from fleshy fruit to a nut.

80. Change from a nut to a caryopsis.

81. Reduction to 3 stamens, through the more prompt determination of the floral axis.

82. Introduction of bilateral condition in the flower, eliminating one lodicule and one stigma.

83. Several flowers in a spikelet to two flowers, through more prompt determination of the spikelet axis.

84. Evolution of potentiality for annual habit.

85. Potentiality added for development of special prop-roots.

86. A special type of embryo evolved with characteristic scutellum.

87. Paired spikelet potentiality added.

88. Tribe potentiality producing hyaline flowering glumes.

89. Progression of time of sex determination to produce extreme monociousness, with the terminal inflorescence staminate and the lateral branches carpellate.

90. Change from scattered pairs of spikelets to spikelets in rows.

91. Introduction of husk-producing potentiality, usually in correlation with the secondary female state.

92. Potentiality for long styles or silks.

93. Development of very long pollen tube.

94. Dimorphism of vegetative stem below the two inflorescences, the internodes in the secondary female state being more or less flexuous.

95. Second flower of carpellate spikelet reduced to a vestige.

96. Complete or nearly complete suppression of vestiges of the opposite sporophylls in the flower. Such vestiges or even perfect sporophylls can easily be brought back experimentally.

97. Development of the cob with suppression of branches of the carpellate inflorescence.

98. Increase in the number of spirals of paired spikelets.

99. Induration of the cob tissues.

100. Partial equalization of the pedicels of stalked and sessile staminate spikelets. This equalization can be eliminated through proper control of the sexual states.

101. A highly unstable and mutative condition of certain characters, especially composition and color of endosperm and pericarp.

PHYLOGENETIC SERIES FROM BACTERIA TO
DICTYOPHORA

Dictyophora is one of the most highly evolved genera of the gasteromycetous Basidiomycetae and below is given a summation of its phylogenetic history as indicated by a summation of the more important fundamental potentialities. The species employed is *Dictyophora phalloidea* Desv. This is a most remarkable tropical plant and has been called a "fantastic fungus flower." It has a vile odor in strong contrast to its fairy-like beauty of form, its main ornament being a long, white, bell-shaped, netted and lace-like appendage, or veil looking like a lace petticoat or crinoline. Unfortunately a lack of ontogenetic investigations on this and related species makes some of the statements uncertain. However, the general nature of the enumerated potentialities is correct.

The higher Fungi may be derived phylogenetically from holophytic, chlorophyll-less Protophyta, or what is more probable from the lower green Algae belonging to the Gonidiophyta. If we take this latter view the first sixteen potentialities will be the same as in the list given for the Dandelion and a loss of chlorophyll and chlorophyll-producing bodies is assumed.

17. Potentiality for the establishment of an original, simple, haploid sexual life cycle.

18. Loss of chlorophyll through development of new potentialities to carry on the nutritive functions.

19. Evolution of potentiality for saprophytism.

20. Change in the nature of the filament to a typical septate mycelium.

21. Change from free naked gametes to copulation between walled cells.

22. Potentiality for developing basidia with four basidiospores.

23. Introduction of a potentiality which produces an incomplete primary sexualization of the gamete nuclei causing a delay in their fusion.

24. Establishment of a binucleate or conjugate phase in the life cycle through a number of vegetative divisions of the conjugate nuclei before their final fusion.

25. Development of clamp connections in the process of conjugate divisions. The clamp connections are to be interpreted as due to secondary sexual states arising in the respective fields of influence of the plus (+) and minus (−) conjugate nuclei at the time of each division.

26. The potentiality which gives the saprophytic, vegetative mycelium a reaction to grow in a subterranean habitat.

27. The potentiality causing rhizomorph development in the mycelium.

28. The potentiality which causes a compact, egg-shaped fruiting body.

29. Complete progressive evolution of the time of incomplete primary sexualization of the conjugate nuclei to the first two nuclei of the germinating basidiospore and consequent elimination of copulation of walled gamete cells. Many of the Gasteromycetae apparently have this type of life cycle.

30. Development of a tough outer peridium.

31. Evolution of the potentiality for the development of a volva gel between the peridium and the separation layer.

32. Differentiation of a separation layer or zone between the gleba and the inner gelatinous layer of the volva.

33. Potentiality for the differentiation of the gelatinous gleba.

34. Potentiality for the differentiation of the reticulate pileus or cap.

35. Potentiality for differentiating a long, elastically expanding stipe, which

breaks through the peridium and carries up the pileus and gelatinous gleba and the campanulate appendage or veil.

36. Potentiality for the polarity of the fruiting body.

37. Potentiality for differentiation of the bell-shaped, netted and lace-like, white appendage or veil.

38. Potentiality for dissolving the mycelium of the gleba into a green gelatinous mass.

39. Potentiality responsible for the shape and character of the basidiospores.

40. Potentiality causing the vile odor of the expanded fruiting body.

If the phylogenetic development is considered to be more direct with no ancestral chlorophyll-bearing stage, the tenth, twelfth, and eighteenth stages of the foregoing summation of fundamental potentialities evolved in the phylogeny will, of course, be omitted.

PHYLOGENETIC SERIES FROM BACTERIA TO SPIROGYRA REFLEXA

Spirogyra reflexa Transeau is one of the higher members of the Conjugatae and shows a much simpler differentiation system and life cycle than *Dictyophora*. The first sixteen potentialities are the same as in *Dictyophora* and in the Dandelion. These are followed by the progressive addition of fundamental properties as given below:

17. Attainment of a slight heterogamy, the one gamete being stationary and the other motile through the conjugation tube.

18. Complexity of the chloroplast pattern.

19. Development of pyrenoids.

20. Evolution of conjugation tube, the gametes never being discharged into the surrounding medium.

21. Unisexuality of the filaments, which

are slightly differentiated as female (+) and male (-).

22. Slight development of secondary sexual states, as shown by the difference between the conjugating protuberances to form the tube.

23. Shape and character of the zygospore and its wall.

24. Degeneration of three of the four reduction nuclei in the zygospore.

25. Development of aplanospores.

26. Specialization of certain cells which do not conjugate, indicating a slight differentiation into vegetative and reproductive cells.

According to the same method of analysis, one of the higher mosses has 27 fundamental potentialities in common with Indian Corn and Dandelion while an ordinary Bacterium has but 8 as compared with 16 for *Spirogyra* and *Dictyophora*.

The four examples given of phylogenetic accumulation of fundamental potentialities will show how each phyletic line with its groups of genera and species has evolved cells of greater or less complexity of reaction and that in general the greater the complement of fundamental hereditary potentialities possessed by a

cell the higher the group of which it is the unit. By a careful study of the whole taxonomic system a much more perfect order of phylogenetic series can be developed and this should be done for all the main series.

In conclusion it must be emphasized that the whole taxonomic system has evolved through additions, step by step, of potentialities which when once established attain a profound stability, that many of the evolutionary movements have very definite limits, and that the segregative potentialities which give rise to phylum, class, order, family and genus limits also establish a series of continuously narrower and narrower bounds within which changes may take place, until finally no more changes are possible except in the minute potentialities or genes. Such changes of or in the genes of the geneticist take place also within the narrow group limits and do not to any extent interfere with or influence the activity of the fundamental potentialities already evolved. If they did we would not have the remarkably orderly taxonomic system or cosmos presented by the plant kingdom but a taxonomic chaos.

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THE PRIMARY FOOD SUPPLY OF THE SEA

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INTRODUCTION

IT has been just forty-one years since the classic monograph *Salpa* by Brooks was published as the second *Memoir from the Biological Laboratory* of Johns Hopkins University (Brooks, 1893). Like many another publication, this memoir contained much valuable discussion of a kind not suggested by its title. On page 147, in the chapter devoted to "Salpa in its relation to the evolution of life," is a section heading "The primary food-supply" which I have adopted as a title for this paper, deeming it appropriate because the primary food supply of *Salpa* is also fundamental to the existence of other marine animals. (See also Brooks, 1894.)

Like many other oceanic observers, Brooks was deeply impressed by the scant visibility of the multitudinous life in the sea, by the extreme prominence of predaceous animals, and by the obscurity of the basic materials necessary for their support. Contrasting the ocean with the land he says: "Our picture of the ocean is an empty waste, stretching on and on with no break in the monotony, except, at long intervals, a floating tuft of sargassum, or a flying fish, or a wandering sea-bird, and we never think of the ocean as the home of vegetable life." Referring to the vast numbers of animals in the open sea he says:

Herring swarm like locusts, and a herring bank is almost a solid wall. In 1879 three hundred thousand river herring were landed in a single haul of the seine in Albemarle Sound; but the herrings are also carnivorous, each one consuming myriads of copepods

every day. In spite of this destruction and the ravages of armies of medusae and siphonophores and pteropods, the fertility of the copepods is so great that they are abundant in all parts of the ocean, and they are met with in numbers which exceed our powers of comprehension.

Continuing, he says: "Insatiable rapacity must end in extermination unless there is some unfailing supply and as we find no visible supply in the water of the ocean we must seek it with a microscope."

Although seeming to us an early observer, Brooks was not the first to attempt to express his amazement at the boundless extent of animal populations of the sea or his interest in the more amazing provision for their sustenance. In his little book *The Ocean* published in London in 1846 Gosse (p. 153) says that in describing the "green water" of thousands of square miles of Arctic seas Scoresby "computes that within the compass of two square miles, supposing these animalcules to extend to the depth of two hundred and fifty fathoms, there would be congregated a number which eighty thousand persons, counting incessantly from the Creation until now, would not have enumerated." In their account of the Zoology of the world voyage of "La Bonite," Eydoux and Souleyet (1852, p. 84) say (free translation): "The pteropods are represented in all seas and all latitudes; indeed we find these mollusks from regions under the equator to the midst of the ice of polar seas: certain species are even so abundant in the northern seas as to form, according to some voyagers, the usual food of the whale."

A strikingly similar statement concerning pteropods is made by Thompson (1877, v. 1, p. 125). In 1882 Moseley, one of the naturalists of the Challenger expedition told the meeting of the British Association for the Advancement of Science that:

Pelagic life then includes the inhabitants of the whole ocean waters, excluding those belonging to the bottoms and shores; that is to say the inhabitants of an area equal to nearly three fourths of the surface of the globe. . . . In point of numbers pelagic animals probably far exceed all others existing. The extraordinary abundance of life, as seen at the surface of the ocean under certain circumstances, when the water is often discolored for miles and its strata absolutely filled with small animals, has often been described by voyagers, but can never be fully realised till it is actually witnessed. . . . The existence of pelagic animals at all is directly dependent on that of pelagic plants.

In 1881, in a lecture delivered at the National Fishery Exhibition, Norwich, England, Huxley (1902, p. 490) says of herring "shoals" having dimensions of sixteen to twenty square miles:

. In these shoals the fish are closely packed . . . every square mile of such a shoal, supposing it to be three fathoms deep, must contain more than 500,000,000 herrings. . . . It is no uncommon thing to find five or six—nay, even ten or twelve—herrings in the stomach of a codfish. (*Footnote*) In 1879 rather more than 5,000,000 cod, ling, and hake, were taken by the Scottish fishermen. Allowing each only two herrings a day, these fishes would have consumed more than three thousand five hundred millions of herrings in a year.

Ryder (1882, p. 240) says:

The remarkable fecundity of the Copepoda explains the extraordinary abundance of the free-swimming species upon the high seas, and even bays, where vast schools of these crustaceans become, in turn, the food of vast schools of herrings, menhaden and shad. . . . The prodigious numbers of herrings and menhaden is a proof of the abundance of the minute pelagic organisms upon which, with scarcely a doubt, it may be supposed they subsist.

In the half century since Moseley, Huxley, and Ryder made their pithy comments many other able observers and writers have affirmed or expanded the material features of their statements. The following list contains the names of a number of those who have been most interesting as well as informative in their efforts to describe the abundance of life in the sea and to state some of the problems of its sustenance and maintenance: Haeckel (1890), Peck (1894), Herdman (1923), Johnstone (1908), Bigelow (1926), Gran (1912), Hjort (1912), Lohmann (1911), and Lebour (1921, 1922, 1923). In vivid portrayal of the boundless extent of life in the sea, Bigelow is at least the equal of any other writer and the wealth of material presented in his *Plankton of the Offshore Waters of the Gulf of Maine* is so far superior that his paper stands alone in its capacity for conveying to the reader an understanding of the eternal pressure of the vast populations of the sea to extend their bounds. Indeed, it is possible that Bigelow's statements as well as those of some other writers may be misleading to certain readers because of this excellence of portrayal of abundance of life in the ocean, or fertility of the sea. In his wonder at the tremendous extent of many marine populations of record, one may lose sight of the fact that a shoal of herring ten miles long and five miles wide (or ten times that size) would occupy only a little of the wide reaches of space available in the open sea. And, in reality, he cannot rightly suppose that even the largest schools remain in existence unchanged throughout the year. In other words, it should be remembered that oceanic populations do not fill all space available in their habitat all of the time. For each area closely crowded in the sea, there are vastly larger areas with thin or

negligible populations at some or all seasons of the year.

In connection with his statements which I have quoted and his phrase ("primary food supply") which I have undertaken to use, Brooks gives to the latter a meaning somewhat more comprehensive than that which I prefer. Under this designation he includes microscopic animals as well as microscopic plants, a usage which does very well for his purpose of pointing out that none of the larger animals of the sea could possibly exist without the presence in abundance of microscopic creatures to furnish sustenance for them or their prey. It suits my purpose better to confine the usage to the microscopic plants equipped with chlorophyll and capable of manufacturing carbohydrates from raw materials, the so-called synthetic organisms. Brooks (1893, p. 147) says:

both observation and deduction force us to recognize that the most important element in the total amount of marine life consists of some half-a-dozen types of protozoa and unicellular plants, of globigerina and radiolarians, and of trichodesmium, pyrocystis, protococcus, and the coccospheres, rhabdospheres and diatoms. Modern microscopic research has shown that these simple plants and the globigerinae and radiolarians which feed upon them, are so abundant and prolific that they meet all the demands made upon them and supply the food for all the animals of the ocean.

Except for the fact that he names only a few groups of microscopic forms it might be said that Brooks includes under the term "primary food supply" the same organisms that are frequently included under the term "microplankton" (the microscopic animals and plants afloat or adrift). A somewhat longer list of such organisms was given by Haeckel (1890, p. 26) as follows:

Protophytes

1. Chromaceae. 2. Calcocyeteae. 3. Murraycyeteae. 4. Diatomeae. 5. Xanthellaeae. 6. Dictyochaeteae. 7. Peridineae.

Metaphytes

1. Halosphaera. 2. Oscillatoria.

Protozoa

1. Infusoria. 2. Thalamorpha. (Foraminifera.)
3. Radiolaria.

Haeckel did not indicate a list with these limits. I have simply taken the part appropriate to my discussion from his general list of plankton forms. This may not exactly coincide with that which would be selected by another but it serves to indicate approximately the limits meant by Brooks and it is not far different from that recognized by present investigators, some of whom would include bacteria and some other plant groups as well as certain other animal groups in the microplankton. The naming would also be slightly different.

Although Brooks gives prominent place to diatoms in stating his views concerning the primary food supply of the sea he is much less emphatic than Haeckel and others in calling attention to their importance. Haeckel (1890, p. 31, free translation) says: "The Arctic Ocean often becomes transformed over wide areas by enormous quantities of diatoms into a thick, dark slime, the 'black water' which constitutes the feeding ground of whales. The pteropods and Crustacea, on which these cetaceans live, feed on the diatom slime, the 'black water' of North Pole travelers." Moseley (1879, p. 566) says:

The surface water of the open ocean is full of vegetable life. Diatoms are to be found with the surface net everywhere, and in high northern and southern latitudes they abound extremely, so as to color the ice with their *débris*, change the tint of the water, fill the towing net with slimy masses and cover the deep-sea bottom with a silicious deposit of their skeletons.

Herdman (1923, p. 312) says: "the plankton which is abundant in most seas at nearly all times must be a valuable

constituent of the food both of young fishes of various kinds and also of adult pelagic or migratory fishes such as the herring and the mackerel." He mentions two groups as having this characteristic; the copepods and the diatoms and goes on to say:

The Copepoda (being animals) feed upon the Diatoms and other allied minute organisms. The Diatoms, being plants, are, however, able to nourish themselves and build up their bodies from the carbon-dioxide and the soluble salts and other substances dissolved in sea water. Diatoms are therefore one of the *producing* groups in the sea . . . while Copepoda are *consumers*.

Johnstone (1908, p. 77) says: "*The Diatomaceae* are above all the most important organisms in the sea regarded from the point of view of their significance as the producers of organic substance. The diatoms are the 'pastures of the sea' and correspond to the 'grass of the fields' of the land." In 1912 Bigelow (1926, p. 431) observed in Penobscot Bay "noticeably soupy" water several miles in extent which contained diatoms of a single species, *Asterionella japonica* Cl. Gran (1930, p. 5) says: ". . . These enormous quantities of diatoms, without doubt, are the most important food for the pelagic copepods and indirectly for the fish larvae which develop after the great spring spawning period." Phifer (1933, p. 43) says:

Marine plants are the principal source upon which the fauna of the oceans depends for the energy necessary for existence. . . . Undoubtedly the shore algae produce organic material forming nutritive substances for bacteria which in turn are probably consumed by small protozoa. However, the phytoplankton are directly consumed and produce organic food in much larger quantities since the areal extent of their distribution is many times greater than that of the shore forms. Of the groups in the phytoplankton, such as diatoms, dinoflagellates, algal spores, coccolithophores, the first mentioned play the major rôle in temperate seas.

Since the testimony of these and many other writers agrees with my own observation that diatoms are the most prominent and the most widely represented of any of the components of the floating plant populations of the sea I shall consider them as fairly representative of the "primary food supply" of the ocean and give to them principal attention in the following discussion.

METHODS OF INVESTIGATION

Inasmuch as the particles of the "primary food supply" are microscopic, and inasmuch as they may be found in only one, in many, or in every drop of water of hundreds of square miles in extent, or at many different depths in hundreds of cubic miles of sea water, it may be supposed that the problem of investigation is not easy. In general, Brooks' assertion "Our picture of the ocean is an empty waste" is more nearly correct so far as surface visibility is concerned than my numerous quotations to show abundance. In order for diatoms to show the "soupy" appearance at the surface noted by Bigelow (an abundance relatively rare in most localities) it is necessary for them to be present in numbers of some scores, or even hundreds, of individual cells to each drop of water. If one wishes to obtain definite information as to where and when they may be found and as to the conditions which favor or hinder their occurrence he must find some way of taking them from the water for accurate observation at the same time that he obtains records of at least a few of the conditions characterizing the water from which they are being taken. Many investigators have puzzled over the problem of reliable investigation of marine plankton (organisms existing afloat or adrift in the sea) without wholly satisfactory results (Bigelow, 1926, pp. 78 and 397) and a volumi-

ous literature has been developed dealing with efforts at its solution. A few items of history will serve to give the trend of these efforts.

Haeckel (1890, p. 1) credits his teacher, Johannes Müller, with being the first (in 1845) to make regular use of a fine meshed net for capturing small organisms by dragging it through the surface water of the sea. Such a method was essentially similar to that of catching fishes by casting a coarse net into the water and dragging it through a school of fishes, the only difference being in the size and shape of the net and of the meshes. Müller used his fine net mainly for capturing the echinoderm larvae in which he was individually interested but both he and his students noticed that large numbers of other things were caught as well. Although Müller may be said to have started the use of systematic methods for investigation of the organisms afloat or adrift in the sea (the plankton) it is generally conceded that Hensen was the one to give impetus to such usage and to give it solid and permanent standing amongst the sciences. Certainly, Hensen (1887, p. 1) was the first to propose and use the word "plankton" as a descriptive name for all of the organisms which exist afloat or adrift in the sea as distinguished from the fishes and other organisms characterized by such powers of locomotion that they are able to change locality irrespective of influences of water movements. In according outstanding prominence to Hensen's influence it should not be forgotten that his improvements in the conduct of plankton investigations were introduced at a time when interest in all lines of oceanic researches had been greatly stimulated by the work of the "Challenger" and other expeditions, and when a lively interest was developing in the productivity of the sea, particularly as related to fisheries.

Roughly speaking, Hensen conceived and developed the idea that over large areas of the sea (the North Sea in particular) the plankton existed in uniform or nearly uniform abundance from the surface to the bottom, or at least to a depth of two hundred meters. This being true, he argued, the productivity of the sea could be estimated from samples taken by drawing an accurately constructed fine net from a designated depth to the surface, his theory being that the net would catch the organisms in the whole column of water beneath an area the size of its inlet. Haeckel (1890) immediately, and many others afterwards, showed that several of Hensen's assumptions are untenable but his methods are still in use to a large extent and all authorities agree that he performed great service by his courage in attempting to obtain useful estimates of the abundance of life in the sea. So far as diatoms and similar organisms of the "primary food supply" are concerned one serious objection to Hensen's method was that no tow net was fine enough to prevent great losses of individual species and specimens through its meshes.

Lohmann (1911, 1912) was especially impressed with the escape of the extremely small creatures through the plankton net and he conducted extensive investigations to show their importance and the possibility of catching them in other ways. He discovered many new species by examining the filtering equipment by which appendicularians (themselves plankton organisms) capture their minute prey and he used a centrifuge for taking others directly from samples of sea water of known volume. By using culture methods similar to those employed for bacteria on land E. J. Allen (1919) confirmed Lohmann's showing of inadequacy of tow net methods and obtained evidence that even the centrifuge did not collect all of the smallest organisms in such a

way as to make them visible under the microscope or available for use in calculating the grand total of planktonic populations. Numerous investigators have tried using filters of different kinds (including sand, paper, and patented devices) with degrees of success more or less satisfactory for researches of definitely limited type. Under certain conditions the method of merely allowing a measured amount of water to stand for a day or two in a settling tube after adding a substance to kill all of the organisms has been found to be fairly successful in collecting them at the bottom of the tube.

In the study of plankton diatoms (the outstanding representatives of the photosynthetic "primary food supply" of the sea) it seems that modern practice in collecting follows three fairly definite different lines. First, the use of the No. 25 mill silk tow net of very fine mesh (mesh openings averaging about 0.05 mm. in diameter) which is still favored by some on the plea of convenience in spite of the known errors of its performance. Second, the centrifuging of samples of water obtained by use of closing bottles, by dipping, or by pumping. Probably Gran (University of Oslo) is making most extensive use of this method to-day, although many others employ it to a greater or less extent. Third, the use of No. 25 mill silk for filtering out the diatoms from measured quantities of water poured or drained through it. The Scripps Institution of Oceanography has made most extensive use of this method, by which it has accumulated nearly 20,000 catches of plankton diatoms since September 1919.

Quantitative treatment of collected material is sometimes volumetric, the volume being read directly from centrifuge tubes or settling tubes appropriately graduated. Less frequently a gravimetric method is used, the material being weighed after

desiccation. Both of these methods have the disadvantage of including debris or unwanted material and they allow no opportunity for satisfactory estimates of relative abundance of different organisms contributing to the mass being handled. More commonly the treatment is by some form of "census taking." Typically for diatoms, a definite fraction of the catch is confined in a Sedgwick-Rafter counting cell (Rafter, 1900, p. 67; Whipple, 1914, p. 35) which holds exactly one cubic centimeter of the fluid. There a part or the whole number of the specimens in the mount is counted and used for making an estimate of the numbers in the total catch.

MARINE PLANKTON DIATOMS

In preceding pages I have quoted a number of authorities (mostly not diatomists) to support the idea that diatoms of pelagic habit are the most widely distributed in space and time, and most prolific of the plant constituents of the "primary food supply" of the sea. In addition, it may be stated that they have been investigated most extensively and continuously of any of these constituents and that the information now available which concerns the "primary food supply" deals mainly with the plankton diatoms. Therefore, it is not only appropriate to select diatoms as representative but it is also almost necessary to do so for practical reasons.

Diatoms are one-celled plants, mostly invisible to the unaided eye except where they are growing in such abundance as to make visible slimy masses on wet surfaces or in water. Their color is usually a pleasing shade of brown which shows a peculiar richness when many are massed together. This color is caused by "diatomin" which covers and hides the chlorophyll green necessary to photosynthesis. They are supposed to be allied to the "Green Algae" (Conjugatae) including

the pond scums and brook silks. Their outstanding characteristic is a rigid siliceous covering fashioned on the fundamental pattern of a pill box, but so modified in many species as to bear little resemblance. The best descriptions of the group (Diatomaceae or Bacillariaceae) are given by West (1916, p. 83), Karsten (1928), Lebour (1930), and Hustedt (1930). Most botanical texts tell little about them and the encyclopedias are the best references so far as ordinary accessibility is concerned. Enthusiastic diatomists consider the sculptural designs on some of the siliceous coats of sedentary diatoms as being amongst the most beautiful things in the world (Mann, 1930), but these beauties are not so evident in most of the plankton forms, which have thinner coverings and more attenuated shapes.

Apparently the first record of observation of a diatom was by Leeuwenhoek in 1702 or 1703 (Taylor, 1929, p. 4; Pelletan, 1891, p. 11). It was a fresh water form but planktonic in habit. Seventy years later O. F. Müller found another species of similar habit, after which records began to accumulate with considerable regularity. Still, it appears that the relationships of diatoms to other organisms attracted relatively little attention until after Hensen (1887) stimulated general interest in fertility of the sea by his efforts to make accurate estimates of the densities of the different kinds of plankton populations occurring together in the ocean. Haeckel (1890), Lohmann (1912), Nathansohn (1906), Herdman (1908), and Ostwald (1903) were prominent amongst European investigators who in the next twenty years gave definite attention to plankton relationships. Of those who gave particular attention in that time to the part played by diatoms in these relationships the following were notable: E. J. Allen (1919),

Cleve (1900), Gran (1912), Ostenfeld (1903), and Schütt (1896).

Although handicapped by less favorable contact with the sea and by wider separation of investigators interested in plankton researches, American interest was just as keen as that in Europe, and American activities ran concurrently with those of Europe. Indeed there is no evidence that any European observer had deeper appreciation of the dependence of life in the sea upon the microscopic organisms than is expressed by Ryder as early as 1882 (already quoted in part). Perhaps Ryder, Brooks, and Peck may fairly be regarded as representing American interest in the importance of the smaller marine organisms at about the time that Hensen was launching his investigations. In addition, Peck may be considered as a leader in America in use of the method of taking small organisms from measured quantities of sea water in an effort to calculate their abundance (Peck and Harrington, 1898).

However, up to 1919 most of the American work had been devoted to plankton animals and relatively little to plankton diatoms. In that year the Scripps Institution of Oceanography of the University of California established a series of investigations, with W. E. Allen in charge, for the primary purpose of gathering authentic information about seasonal and geographical occurrence, distribution, and conditions of abundance of plankton diatoms in the Eastern Pacific. More recently additional particular attention has been given to diatoms by certain investigators under the leadership of Gran at the Friday Harbor Marine Station of the University of Washington (Phifer, 1933) and a considerable number of discontinuous studies have been made at certain points on the Atlantic coast, notably in the Gulf of Maine region and localities near Woods Hole (Bigelow, 1926; Fish, 1925).

DIATOM RESEARCHES AT SCRIPPS INSTITUTION

In 1919, the Institution adopted as standard for collecting marine plankton diatoms the method of dipping from the sea a certain quantity of water and draining it through a small conical filter made of No. 25 silk bolting cloth (W. E. Allen, 1921). Assuming that there would be considerable losses of the smaller specimens through the meshes of 0.05 mm. diameter it still appeared that enough would be caught to give a fair index of abundance, while permitting the collection to be made quickly, easily, and with an accuracy at least as great as the accuracy of selecting a sample from the great mass of water constituting the ocean. However, the most important advantage of such simplicity of method is that it can be used under almost any conditions, thus insuring that a valuable series once begun need not be broken on its account, and also encouraging the taking of collections by reliable persons lacking in skill and training. Thus it has been possible to keep collections going daily at two Southern California piers for fourteen years and to get series of surface catches at hourly or longer intervals from several different kinds of ships under full speed at sea. The results of these diatom investigations have been given in a number of reports by W. E. Allen (1921, 1922, 1923, etc.) and his assistants. At present, it seems to be more appropriate to this discussion to confine attention to a limited number of selected topics than it would be to attempt to summarize the details of these reports.

THE PROBLEM OF UNIFORM DISTRIBUTION

One of the strangest phenomena in the history of science is the perpetuity of certain ideas, theories, or assertions after they have been shown to be untenable. One might suppose that scientific training

would enable its beneficiaries to avoid this trait of humanity in general but there is considerable evidence that it does not. The history of Hensen's (1887) assumption that plankton is uniformly distributed in sea water over a wide area and to considerable depths illustrates this point. Haeckel (1890, p. 57) objected to it almost immediately. Herdman (1922) noted that even when simultaneous tow net catches are alike in quantity they may be far different in quality (in the kinds of organisms included). Bigelow (1926, p. 78) says "even a cursory examination of the zooplankton, if extended over a considerable area or through a considerable period of time, is certain to reveal wide fluctuations in abundance as well as in its quantitative composition, both from season to season and from place to place." (Cf. p. 403.) Many other investigators have reached similar conclusions, but even to-day there are probably considerable numbers of people who accept Hensen's assumption. The reason for this attitude may exist in the fact that Hensen qualified his assumption by saying that it would apply wherever the conditions of the water itself were uniform, a condition which is now known to be rarely found even on the surface, much less at any given level or at successive levels below the surface within the range of plankton occurrence.

Realizing that a part of the difference of opinion concerning the validity of Hensen's assumption might be due to experiences in different regions and with a view to getting a considerable body of evidence bearing on the question as related to diatoms, as well as for certain other reasons, two collecting stations (positions) were selected respectively five and ten miles off shore from the Scripps Institution pier and visited regularly for parts of seven summers in the last fourteen years. In every year it was found that there were

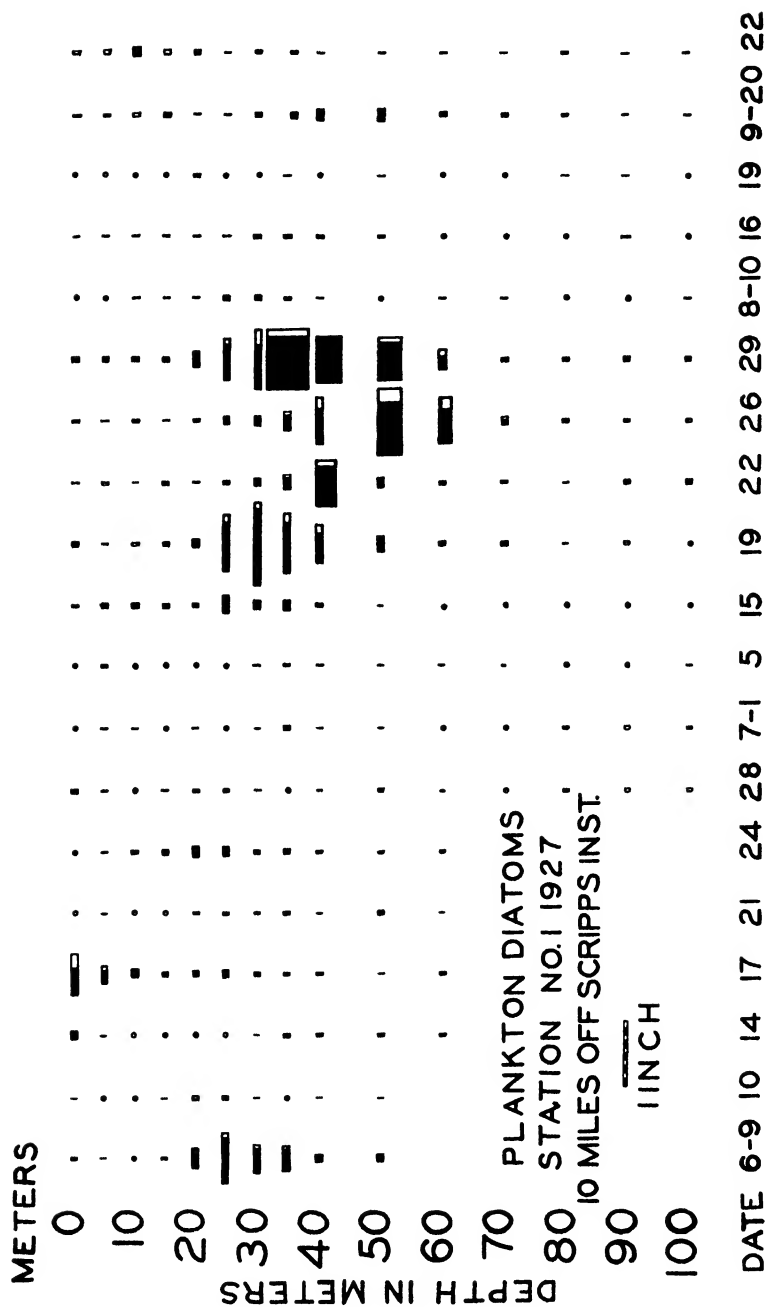


FIG. 1. GRAPH TO SHOW RELATIVE ABUNDANCE IN NUMBERS OF CELLS AT DIFFERENT LEVELS BELOW THE SEA SURFACE AT STATION 1 IN JUNE-JULY 1927

Shaded areas in rectangles represent percentage in good condition, unshaded in bad condition

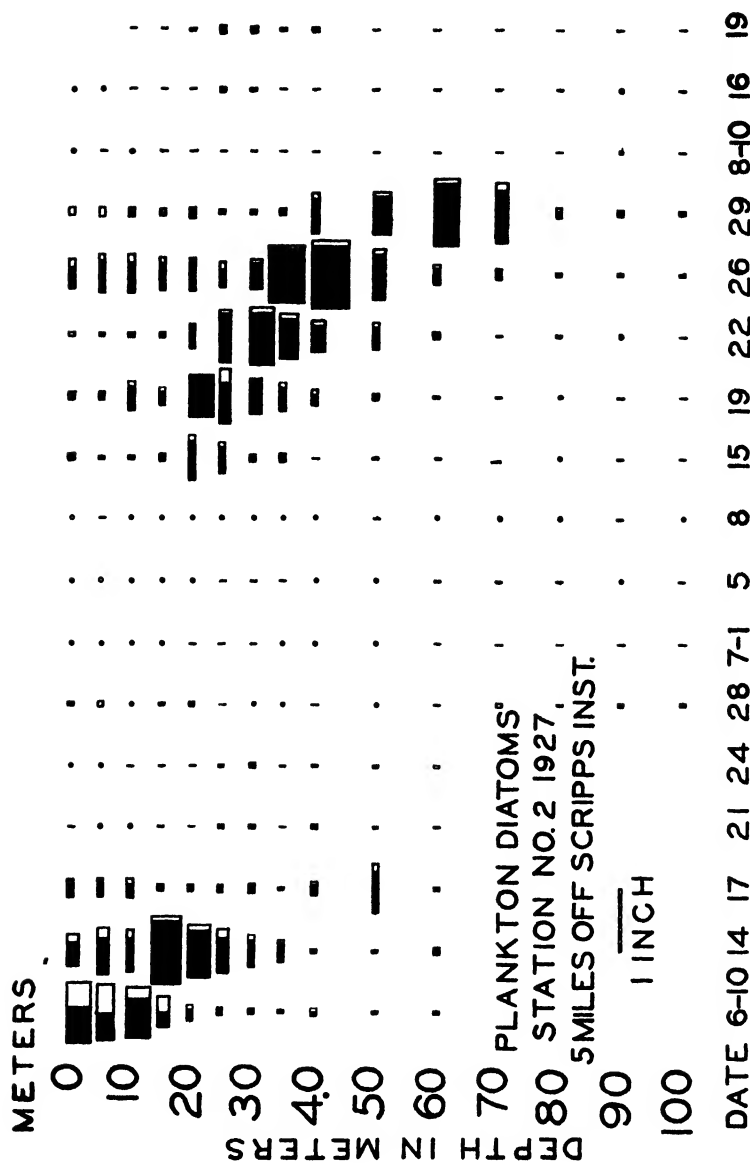


FIG. 2. GRAPH TO SHOW RELATIVE ABUNDANCE IN NUMBERS OF CELLS AT DIFFERENT LEVELS BELOW THE SEA SURFACE AT STATION 2, IN JUNE-JULY 1927

Shaded areas in rectangles represent percentage in good condition, unshaded in bad condition

considerable differences in the surface catches at the two stations, abundance being greater at the five mile station more frequently than at the ten mile station, although the reverse was true in many

was lacking not only at the two stations but between them and the shore. In 1926 (W. E. Allen, 1928) and again in 1927 (W. E. Allen manuscript) series of catches at five and ten meter intervals were ob-

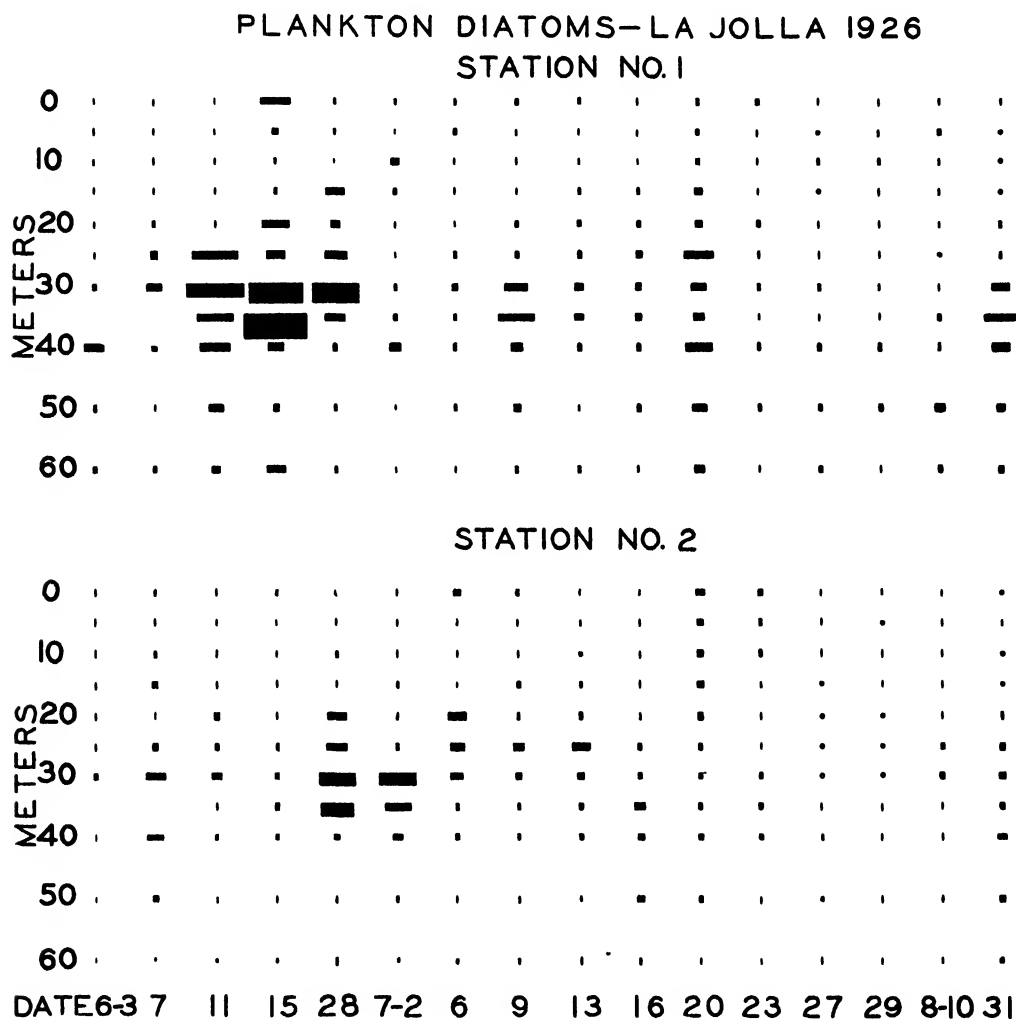


FIG. 3. GRAPH TO SHOW RELATIVE ABUNDANCE IN NUMBERS OF CELLS AT DIFFERENT LEVELS BELOW THE SEA SURFACE AT STATION 1 (10 MILES OFF SHORE) AND STATION 2 (5 MILES) IN JUNE-JULY 1926

Large shaded rectangles represent large numbers, smaller less

cases. Even in 1924 (Sleggs, 1927, p. 102) when there was an occurrence of "red water" in the area, which persisted for more than a week (showing great stability of conditions), uniformity of abundance

tained by the Allen closing bottle at both stations in which striking differences in abundance of diatoms appeared at every level, the catches at both stations being taken in the same forenoon at each time.

However, in these two instances the differences were in abundance rather than in constituents, the principal species at both stations being *Thalassiothrix frauenfeldii* Cl. and Grun. in 1926, and *Nitzschia seriata* Cl. in 1927. The gross features of differences in abundance at all levels sampled at the two stations are graphically indicated in fig. 3 for 1926 (Cf. W. E. Allen, 1928) and in figs. 1 and 2 for 1927, in which the graphs, though smoothed to a considerable extent by using decimal orders of magnitude to represent the actual numbers, show astonishingly greater abundance at certain levels. From this and other evidence accumulated by the Scripps Institution over a period of thirty years it appears certain that uniformity of distribution of plankton in sea water, either horizontally or vertically, is practically nonexistent in Southern California waters at any time, whatever may be the condition in some other oceanic locality.

SEASONAL DISTRIBUTION

Bigelow (1926, p. 465) says "Perhaps no phenomenon in the natural economy of the gulf so arrests attention (certainly none is so spectacular) as the sudden appearance of enormous numbers of diatoms in early spring, and their equally sudden disappearance from most of its area after a brief flowering period." Johnstone (1908, p. 97) says "May begins a new season. The diatoms have hitherto been prominent plankton organisms, often to the exclusion of everything else, but from now for a few months they begin to decrease in numbers." Gran (1930, p. 5) says "It is a characteristic feature of the plankton production off the coast of Norway that after the dark winter months, as soon as the light is sufficient for their photosynthesis, there is an enormous growth of pelagic diatoms." Similar comments have been made by many other observers, mostly from North Atlantic or

North Sea regions. Since their latitudes are higher by distances of a thousand miles or more than those of Southern California the interest of obtaining data for comparison was added to that of learning the actual facts of seasonal occurrence when the Scripps Institution began the investigation of plankton diatoms in the San Diego region.

In order to insure that continuity of daily collecting throughout the year should not be broken, piers were selected as stations for obtaining samples of sea water from which the diatoms might be extracted. The Institution pier was used for one, a pleasure pier at Oceanside, twenty miles north, was used for another (for six years only), and a pleasure pier at Pt. Hueneme, over one hundred miles north was also selected. At all of these stations there was somewhat the same tendency as has been noted for northerly latitudes for maximum abundance of diatoms to appear in the first third of the year. However, no two years were alike in the ten years for which the study of data has been completed and most of the peaks of abundance were not coincident at the two more widely separated stations. In the ten years there was a fairly distinct indication of a tendency for increase of abundance to begin at the Institution pier five or six weeks before it began at Pt. Hueneme although the actual maximum at both stations seemed to tend to be reached in or near April, and was sometimes as late as June (once in September) at the Institution pier. The authors quoted, and most others referring to the phenomenon, attribute the vernal increase ("flowering" or "efflorescence") of the plankton diatoms to increase in light, to increase in temperature, and to surplus nutrients (accumulated in the waters in the less productive months of winter). One cannot escape the conviction that

these conditions must play a large part in accounting for the vernal increases in abundance in Southern California as well as elsewhere, but the explanation is really not so simple as that, else why should an abundance sustained near to the April maximum for some weeks appear (at the Institution only) in February of 1920 and not in other years?

YEAR DIFFERENCES

Biologists (as well as other people) not familiar with the inconstancy of unrestricted Nature might suppose that daily observations on a particular kind of organisms for a year would give a reliable understanding of the conditions of its existence in a particular locality. As a matter of fact, such a body of information may be misleading to a greater or less extent in a number of different ways, some of which are well illustrated by experiences in the Southern California region.

In a preceding paragraph I mentioned the fact that *Thalassiothrix frauenfeldii* was the most prominent diatom in boat catches for 1926. This was the only year that it has attained such prominence in Institution material. Indeed, it is inconspicuous or missing in the catches of most years. Still, any one depending on the information for that one year would feel fully warranted in saying that that particular species was a conspicuous and characteristic feature of the diatom flora of the Gulf of Santa Catalina. Other examples not quite so striking appear in the Institution records.

For the year 1920 (W. E. Allen, 1922a) the total diatoms for the year obtained by daily catches at the Institution pier were considerably larger than the total from similar catches at Pt. Hueneme. This appeared to offer good foundation for an inference that La Jolla sea water was more productive than Pt. Hueneme sea water.

In 1921 (W. E. Allen, 1927) there was less difference but still a greater total abundance at La Jolla. If the records had stopped with that year the conclusion would be readily accepted anywhere that the fertility of the sea was greater at the more southerly station. But continuance of the observations showed that in succeeding years there was a reversal, with Pt. Hueneme more often in the lead in individual years of the ten. Even two years was not sufficient to give a reliable idea of the relative productivity of the two localities.

E. J. Allen (1908, p. 397) has commented on the showing of Bullen (1908, p. 269) that there appeared to be a correlation between the number of mackerel taken in May and the number of copepod food organisms in their vicinity and suggested that since the copepods depend on plant food there ought to be a further connection between the amount of sunlight in February and the abundance of plants (plankton diatoms). He examined sunshine records and such fisheries records as were available and came to the conclusion that "they indicate a fundamental correlation between the abundance of mackerel in May and the amount of bright sunshine during the earlier months of the year." Even though his conclusion be questioned, it has the important use of calling attention to the generally accepted view that sunshine in the early months of the year is favorable to diatom production, and through it to the increase of vast numbers of different kinds of animals, many in larval or immature stages of development. Assuming the reality of this relationship it is easy to understand that if the diatom increase comes late in the season of a particular year it may be too late to feed enormous populations of young animals of that year, including some of the fishes. In other words, it is not only important that

there should be adequate production of the plants but that it should come at a time of year favorable for many animals. Harvey (1928, p. 165) says:

It cannot be assumed that where vegetable carbohydrate and protein food exist, there will be an animal population to eat a *fixed* proportion of it. Besides a supply of phytoplankton suitably spaced in time, a further condition necessary for maximum population is that the energy of plant life passed on to the plankton-feeding animals should, before they die, be handed on to the carnivorous animals.

Lacking in necessary approach to a coincidence with animal needs, plant productivity ceases to be a reliable index to fertility, and it may be that the smaller amount of one year or place is more serviceable in the economy of the sea because it is timed more appropriately than the larger amount of another year or place. Therefore, the early and sustained abundance in La Jolla Bay in 1920 may have made it superior to any other year of the ten in respect to general conditions of fertility. As a matter of fact, mackerel fishing was exceptionally good at the Institution pier that year, indicating some degree of correlation, so far as the evidence goes.

LOCALITY DIFFERENCES

Just as certain localities are known to be more favorable than others for catching marine fishes, so certain localities are known to be especially favorable for plankton organisms, including the diatoms. The great abundance of plankton organisms, including diatoms, on the Malabar Coast of India as reported by Hornell and Nayudu (1924) shows that region to be exceptionally favorable. For many years it has been known that a particular species of diatoms is to be found in astonishing abundance at a certain time of most years on Copalis Beach (near Gray's Harbor) in the State of Washington as is mentioned by Galtsoff (1932). Gran (1915) compares sta-

tions in a number of different localities and refers (p. 129) to the exceptional abundance of a single species "round Scotland and the Faeroes." The records of diatom occurrence obtained by the Scripps Institution in a period of more than fourteen years give many indications of locality differences, a few of the more striking being as follows: Daily catches at Farallone Light (about thirty miles seaward from San Francisco) over a period of four years, when abundance was good at Southern California stations, never showed more than negligible occurrence of any kind of micro-plankton. In several series of catches taken by ships plying between San Diego and Seattle catches taken near Destruction Island (off the Washington coast) have been notably larger than others while those from a number of other localities represented in each series have always been small or negligible. Similarly the catches near Abreojos Point in Lower California have appeared notably large in series obtained south of San Diego. These and similar differences are even more impressive if one considers the constituent species as well as total abundance, as is necessary in extensive investigations.

For many locality differences it appears to be fairly evident that topography is responsible. Bigelow (1926, p. 391) says "The fertility in diatoms of the waters over Georges Bank is interesting," and "The prevalence of the genus *Guinardia* on the bank, contrasted with its absence or rarity in the deeper waters of the gulf to the north" and "Turning now to the coastwise belt, diatoms continue a more important factor in the phytoplankton of estuarine situations throughout the summer than they are in the open waters of the deeper parts of the gulf at that season." Numerous other writers indicate similar observations and views, some of them emphasizing the influence of upwelling or

other turbulence caused by bottom or shore line topography of a particular region.

For other locality differences it appears to be assumed by some writers that differences in latitude are mainly influential. Harvey (1928, p. 178) gives certain really good reasons why high latitudes may be more fertile. Johnstone (1908, pp. 202-205) expresses the positive opinion that "the productivity of the sea" is greatest in arctic or sub-arctic regions and he mentions or quotes a number of corroborative statements of various observers and authorities. He says: "Thus the colder seas are richer in life than the warmer ones; or at the very least the amount of life in polar seas is not less than in the tropics." He quotes Kjellman: "One stands as before an insoluble problem when he makes a haul with a tow-net in the Arctic and obtains abundant and strong vegetation, and this at a time when the sea is covered with ice, the temperature is extremely low, and nocturnal gloom predominates even at noon." Comments even more emphatic have been made concerning the diatom production of Antarctic seas. While not antagonistic to such statements and ideas the Scripps Institution of Oceanography long ago suggested the desirability of testing their degree of accuracy: first, because such sweeping generalizations do not seem justified in the absence of concurrent comprehensive surveys of actual production in both low and high latitudes, through at least one annual cycle (preferably several); second, because the reports from high latitudes appear to deal entirely with conditions at the surface level; third, because the most extreme statements concerning excessive abundance of plankton in high latitudes appear to be based on incidental notice rather than on substantial series of careful observations. Avoiding voluminous arguments and citations, perhaps it is permissible to pass this point

with the statements that records of the Institution covering sub-tropical latitudes over a period of years show a considerable productivity in some localities, not only at the surface, but to depths as great as sixty meters below the surface (fig. 2), and others covering sub-arctic latitudes which show many localities lacking high productivity at a time when neighboring localities were prolific. With such evidence in hand it seems that generalizations concerning the relative productivity of low and high latitudes are not tenable on the basis of data yet available. (Cf. W. E. Allen, 1923, 1925, 1927a, 1929). So far as species composing the populations of plankton diatoms are concerned, many are to be found at times from Panama to Alaska but the genus *Thalassiosira* is much more conspicuous in the higher latitudes.

The evidence obtained by the Scripps Institution as well as that of most literature on plankton supports the view that the high sea is not strongly productive of plankton. Along the Southern California coast the greatest productivity is surely within fifty miles of shore. In other seas, more shallow water or shoals may present influences resembling or helping to conserve those of proximity to exposed land in such a way as to greatly extend the productive area in relation to visible land. Gran (1915, p. 133) has long supported the hypothesis "that the great amount of plankton which occurs in the coastal waters and from thence can spread far out to sea, is first of all due to a permanent supply of nutritive substance from land" and this seems to be in substantial agreement with the views of most other investigators, including those of Southern California. While not supported by enough specific data to be incontestable there is reason for thinking that "flood years" in the San Diego region are especially favorable for production of plankton in spite of the

serious interference to runoff due to impounding of the waters. But even a "flood year" in a semiarid region does not yield enough land materials to carry influence very far to sea and it is probable that the land influence in Southern California more often favors greater productivity near shore by causing "upwelling" in its vicinity (Michael, 1921; cf. Harvey, 1928, p. 168).

SOLAR RADIATION

There seems to be general acceptance of, and no objection to, the idea that solar radiation influences life in the sea no less than it affects that on the land. Russell (1927) says "Light is absolutely necessary for the life of all the floating plants" and "That light is an important factor in the behavior of animals is well known." Nevertheless, the details of operation of radiation influences, the phenomena of their transmission and delivery to each organism in the sea, and the identifications of their results in particular cases are still obscure. This is especially true of the phytoplankton, in which the immediate or measureable responses to influence are less easily traced than is the case in some researches on plankton animals. Marshall and Orr (1927) say: "Although sunlight is necessary for photosynthesis, too much of it is injurious. It has been found that diatom cultures grow best away from direct sunlight. . . . Even in the sea, it is possible that in summer the actual surface layer is not the optimum position for diatoms." Figures 1, 2, and 3 appear to support this supposition for the Southern California region, at least in mid-summer, but Moberg's (1928) study of chemical influences affecting the catches represented in these graphs shows that other conditions also favored greatest abundance at several meters below the surface.

RELATION OF DIATOMS TO ANIMALS

In preceding pages of this paper a number of authoritative statements have been quoted to show the importance of diatoms as one of the links in the food chains of the sea. Some of the best direct evidence available was obtained at the Scripps Institution by Esterly (1916, p. 182) who found that "An examination of the digestive tracts of several species of marine copepods shows that diatoms are the organisms whose remains appear most often." However, Esterly himself notes (on the same page) that the food of copepods probably consists largely of organisms lacking shells or other means of leaving recognizable remains. Still the general emphasis on the food values of diatoms is so great that there is risk of forgetting the possibility of other relationships. In particular, it is possible that certain kinds of diatoms may be poisonous to animals (or to certain animals) just as certain land plants are known to be so, and it is possible that when present in great abundance they may interfere more or less with respiration of some animals by clogging the gills. Direct evidence in support of these possibilities is not available in Southern California except that commercial fishermen say that fishing is not good where diatoms are so abundant as to discolor the water. Bullen (1908, p. 291) examined a sample of "stinking water" from the English Channel such as fishermen said indicated absence of fish (mackerel) and found a preponderance of phytoplankton over zooplankton. And since it is known that certain kinds of dinoflagellates (other phytoplankton often occurring with diatoms) sometimes cause great destruction of inshore forms of animal life (Torrey, 1902) it is reasonable to suppose that diatoms may become deterrent or deleterious to animal life under certain circumstances.

CLOUD THEORY OF PHYTOPLANKTON
OCCURRENCE

In general discussion of occurrence and distribution of plankton in terms of abundance one is driven by necessity to the use of statements and modes of expression much more definite than are justified by the facts, either known or surmised. Thus arises the apparent absurdity of speaking of the productivity of thousands of square miles of Southern California seas in a given day, week, month, or year when the only evidence available is that obtained from a few pints or gallons of water at a single convenient point. However, this absurdity is more apparent than real so far as characterization of the region as a whole is concerned, the error in exact representation of conditions at any other one point, as compared with the observation point, being partly offset by the *approximation of representation* of the observation point when compared with *all* points belonging to the area. A meteorological observer succeeds in giving us a fairly good working idea of conditions in his region in spite of a wide range of differences at different points in the ocean of air (the atmosphere) when he reports "cloudy" or "partly cloudy" at his station. There is good reason for thinking that an oceanographical observer may succeed in giving a similarly useful general idea of conditions in his region of the ocean of water by reporting the differences in abundance of plankton occurring at his station, although the range of differences may be very wide at different points belonging to the area.

Not only is there this general analogy of practical usefulness of characterization of regional conditions from narrowly localized observations in the two kinds of oceans, but there is also a considerable resemblance in the formation of clouds of

different substances in the two kinds of media. While we most often refer to clouds of water vapor when we speak of clouds in air, we also frequently speak of other clouds such as "clouds of smoke," "clouds of gnats," "clouds of dust" and the like. It is, therefore, quite natural to speak of clouds in water and in the ocean. And, in the case of phytoplankton, the usage is commendable because the term cloud leads us to think of plankton occurrences as being similar in appearance to those of water vapor in air which are so familiar to us. In our actual experience we sometimes see rather dense aggregations of plankton in a small area which look in shape and density very much like some of the little clouds of water vapor we see sometimes in the air. When the sea is discolored for miles as described by Moseley and by Haeckel as quoted in the early part of this paper the condition is comparable to that of an "overcast sky." More frequently there are intergradations between these extremes, or perhaps most frequently the resemblance is to those thin clouds scattered about the sky as wisps, and flowing banners, and weird, translucent canopies of fantastic form with highly irregular space relationships. This is particularly true of the minute plants such as diatoms and photosynthetic dinoflagellates which constitute much of the more strictly primary part of the food supply of the sea. Both from boats and from the ends of piers one may see at certain times slight streaks, smears, or tinges of discoloration of the surface of the sea which have form and extent similar to that of many of the thin clouds of vapor in the sky above them. At any rate, there can be no doubt that the idea of plankton clouds has a distinct value as a counterbalance to the idea which might otherwise be allowed to grow in our minds that oc-

currence and distribution of plankton in the sea is uniform or regular in detail in relation to either space or time.

CONCLUSION

In concluding a cursory survey of a field so extensive as this, it is surely appropriate to make a few remarks concerning the general food relationships of the ocean in which photosynthetic organisms assume a conspicuous position. In case of simple death of a diatom (or other phytoplankton) cell, it may be supposed that decomposition by bacteria or other saprophytic forms brings derivatives from the body substance to a soluble or suspended condition in the surrounding water, from which some of

them may be removed by another diatom cell for its own use. For some particular atom it may be possible for the circuit to be very short, i.e. diatom—bacterium—sea water—diatom. In most cases it is longer as: diatom—copepod—herring—cod—bacterium—sea water—diatom. (Harvey, 1928, p. 168, gives an excellent diagram illustrating the general possibilities.) Long or short, there is no room for doubt that photosynthetic organisms occupy the key position in the general circuit of food exchanges in the ocean, and that they must be reckoned with sooner or later, even though one may choose, like Brooks, to include animal microplankton under the convenient term of "primary food supply."

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THE NERVOUS SYSTEM OF THE EARTHWORM

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THE nervous system of the earthworm has doubtless received the attention of more morphologists and physiologists than has that of any other invertebrate. Since it is still frequently used in investigation, it is of importance to ascertain the present state of knowledge concerning its structure and function and the manner in which this knowledge has been accumulated. The literature dealing with the nervous system of earthworms (*Lumbricidae* and allies) has been treated in several monographs, among which the most recent is by Stephenson (121). The present account aims to show how the nervous system of the adult earthworm has been used as material in the study of invertebrate neurology in general.

HISTORICAL DEVELOPMENT

Very few papers dealing with invertebrate nervous systems appeared before 1800. The first accounts were brief descriptions of the principal gross components, culminating in those by such naturalists as Cuvier. Then followed a period of interest in comparative morphology during which the parts of the nervous system in different animals were compared. During this same period (approximately from 1825 to 1850) a few microscopists applied their methods to nerves in different organisms and distinguished between globules and tubes (nerve cell bodies and fibers). Near the middle of the century the interest in comparative morphology led to phylogenetic studies aiming to show relationships among and within groups on the basis of similarities in structure. About 1870 interest in

special histology came to the front, and an attempt was made to describe the details of different components of the nervous system, and from this knowledge to reason concerning their function. Fixed and stained tissues came to be used more generally, and three problems were uppermost: the origin and nature of nerve "tubes," the nature of the connections between them in the central nervous system, and the structure of the nerve cells. Since 1890 increasing emphasis has been upon the function of the nervous system. This has led to experimental work such as the study of motor coördination in intact and operated specimens and the use of drugs and of electrical methods. Some of the inferences concerning function that were drawn from the structure of the nerve elements have been substantiated while others have been disproved.

The development of interest in the nervous system of the earthworm closely paralleled this general development of invertebrate neurology. The occurrence of papers dealing primarily with gross morphology, histology, and physiology of the nervous system of the earthworm in different countries is indicated in table 1. This table shows that the first histological study appeared nearly forty years after the first account of gross morphology of the nervous system and that the first physiological paper appeared approximately thirty years after the first histological one.

It shows that each subject has been studied in cycles. For example, peaks of interest in the histology of the nervous system appeared during 1861-1865, 1891-

1895, 1906-1915, and 1926-1930. The peak in 1891-1895 is definitely correlated with the application of methylene blue and Golgi methods to invertebrate material, the others with more general interests of the periods. The recent high

1925, and the indication is that another will be reached during the next few years.

This table also shows that most of the gross morphological studies were done in France and England, that in the histological investigations Germany leads,

TABLE 1

Occurrence of Papers Dealing with the Gross Morphology, Histology, and Physiology of the Nervous System of the Earthworm from 1816 to 1933. Papers Dealing with Regeneration Are not Included. Countries are Those in Which Work was Done; Some Papers from Other Countries Are not Included

YEARS	GROSS MORPHOLOGY						HISTOLOGY						PHYSIOLOGY					
	France	Germany	England	U. S. A.	Japan	Total	France	Germany	England	U. S. A.	Japan	Total	France	Germany	England	U. S. A.	Japan	Total
1816-'20	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
1821-'25	—	2	1	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—
1826-'30	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
1831-'35	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1836-'40	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
1841-'45	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1846-'50	2	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
1851-'55	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
1856-'60	—	—	1	—	—	1	1	—	—	—	—	1	—	—	—	—	—	—
1861-'65	1	—	2	—	—	3	—	3	1	—	—	4	—	—	—	—	—	—
1866-'70	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—
1871-'75	2	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—
1876-'80	—	—	—	—	—	—	1	1	—	—	—	2	—	—	—	—	—	—
1881-'85	1	—	—	—	—	1	1	1	—	—	—	2	—	1	—	—	—	1
1886-'90	—	—	1	—	—	1	2	3	—	—	—	5	—	2	—	—	—	2
1891-'95	—	1	1	—	—	2	1	6	—	2	—	9	—	2	—	—	—	2
1896-'00	—	—	—	1	—	1	2	3	—	—	—	4	—	3	—	—	—	3
1901-'05	—	—	—	—	—	—	—	3	—	—	—	3	—	3	—	1	—	4
1906-'10	—	—	—	—	—	—	5	2	—	—	—	7	—	—	—	1	—	1
1911-'15	—	—	—	—	—	—	2	6	—	—	—	8	—	—	—	3	—	3
1916-'20	—	—	—	—	—	—	1	1	—	1	—	3	—	1	—	4	—	5
1921-'25	—	—	—	1	—	1	—	—	—	4	—	4	1	2	—	5	1	9
1926-'30	—	—	—	1	1	2	—	—	1	5	4	10	—	1	—	3	—	4
1931-'33	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1	3	—	6
Total.....	9	3	7	3	1	23	16	29	2	12	4	63	1	17	1	20	1	40

peak in this field indicates that the next decade will not be particularly productive of papers dealing with the histology of the nervous system of the earthworm. Similarly, papers dealing with the physiology of the nervous system of the earthworm reached peaks in 1901-1905, 1921-

while second place is nearly equally shared by France and the United States. Further, Germany and the United States have nearly equally contributed to the physiological papers, with almost none from other countries. In each subject the shift has been toward the United States in recent years.

GROSS MORPHOLOGY OF THE NERVOUS SYSTEM
OF THE EARTHWORM

In 1672 Willis (135) recognized a white lobe above the oesophagus of the earthworm as the brain, "cerebrum mole perexiguum." Cuvier (26) was one of the first to identify the divisions of the nervous system of the earthworm. He observed the ventral nerve cord, two pharyngeal commissures and the dorsal brain or suprapharyngeal ganglion. Referring to *Lumbricus* he said, "Le cordon nerveux n'est qu'une suite d'une infinité de petits ganglions serrés les uns contre les autres."

Leo (78) and Roth (111) also identified these parts, and Home (57), Morren (88) and Anderson (1) added more details. Home figured two anterior nerves arising from the brain of the earthworm, one from each pharyngeal commissure, one pair from the subpharyngeal ganglion, and two or three pairs from each remaining ganglion. Anderson stated that two pairs of nerves emerge from each ventral ganglion and two pairs from the cephalic ganglion or brain. He considered the second and third segmental nerves to constitute one single root. Thus by 1840 the gross components of the nervous system of the earthworm had been identified.

In 1848 Blanchard (8) advanced the idea that each class of invertebrates has its own basic pattern of nervous system and that the arrangement of ganglia can be used as a basis of classification. He supported this contention by a study of a variety of groups including earthworms. In using this new method of classification Quatrefages (103) maintained that the number of segments in earthworms and leeches is determined by the number of ganglia rather than by the external segmentation. Perrier (96, 97, and 98), Benham (5), and Beddard (4) also made comparative studies of the nervous system of different species

of earthworms. They used the position of the brain, the number of cerebral nerves, the degree of separation of the ventral ganglia, and other variations in the central nervous system as a basis of classification, and showed that there are appreciable differences in the nervous systems of different species.

Clarke (23) made the first really detailed study of the ganglia of *Lumbricus*. He described the brain as a bilobed mass giving rise to the pharyngeal crura or commissures and to two cephalic nerves which branch to the upper and lower prostomium. In the brain he distinguished an outer cellular lamina and an inner fibrous mass, a fan-like spreading of the roots of the prostomial nerves and a transverse band of fibers between the two lobes. He homologized the dorsal part of the cephalic ganglion with the lower part of the ventral chain because of the similar distribution of cells in each, and drew an analogy between the transverse commissure in the brain and either the corpora quadrigemina or corpus callosum.

In 1865 Udekem (129) published some colorful but inaccurate plates in which he showed nerves leaving the cord and branching symmetrically among the muscles. The distribution of the peripheral nerves was treated more completely, however, by Hesse (54), Fling (31), and Hess (51). Hesse maintained that the first and third nerves in a segment are mainly motor and that the second nerve serves most of the sense organs in the segment. He described the innervation of the anterior end in *Lumbricus herculeus*, and Hess described it in *Lumbricus terrestris*. Hess used both gross dissections and serial sections in tracing the nerves. His general results are presented in figure 1. This figure shows that the pharyngeal commissures innervate the first segment and that the anterior part of the subpharyngeal ganglion inner-

vates the second and third, the posterior part the fourth segment. This indicates that the subpharyngeal ganglion probably represents the fusion of three segmental ganglia. Hess states that the caudal segment has either five or six pairs of nerves and that each pair of segmental nerves forms a complete ring around the body. According to Fling, the branches of these nerve rings overlap on both the dorsal and

In addition to the ganglia and the nerves arising from them, there is in the earthworm a pharyngeal plexus which was first described by Quatrefages (102.) and later by Clarke (23). The former said that six branches from each pharyngeal commissure are connected with a nerve plexus over the pharynx, the latter that four or five short branches from each commissure extend to the plexus. In 1865 Lankester

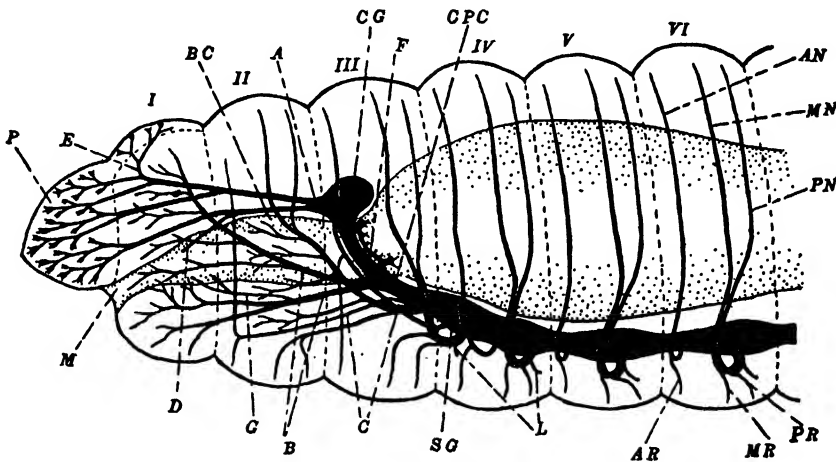


FIG. 1. DRAWING SHOWING A LATERAL VIEW OF THE ARRANGEMENT OF THE LARGER NERVE TRUNKS IN THE LEFT HALF OF THE ANTERIOR SEGMENTS OF THE EARTHWORM, *LUMBRICUS TERRESTRIS*

A, nerve from lateral region of cerebral ganglion which passes to prostomium; AN, dorsal ramus of anterior segmental nerve, AR, ventral ramus of anterior segmental nerve; B, nerve from near middle region of circumpharyngeal connective which passes to segment 1; BC, buccal cavity; C, nerves from ventral region of circumpharyngeal connective which pass to segment 2; CG, cerebral ganglion; CPC, circumpharyngeal connective; D, branch of nerve to prostomium that supplies tissues of dorsal region of buccal cavity; E, nerve that supplies the portion of the prostomium in the dorsomedian region of segment 1; F, gangliated thickening of enteric nerve plexus; G, branch of nerve to segment 1 that supplies tissues of ventral region of buccal cavity; L, septal nerve; M, mouth opening; MN, dorsal ramus of median segmental nerve; MR, ventral ramus of median segmental nerve; P, prostomium; PN, dorsal ramus of posterior segmental nerve; PR, ventral ramus of posterior segmental nerve; SG, subpharyngeal ganglion; I-VI, segments 1 to 6.

(This figure was drawn by Dr. W. N. Hess and is reproduced by his permission.)

ventral sides. Fling also stated that the posterior segmental nerves gives branches to the septa and intestine in addition to the musculature.

The nervous system of *Perichaeta megascolidioides* (Imai, 62) is peculiar in that eight to ten cerebral nerves leave the borders of the cerebral ganglion and supply the prostomium, buccal cavity, and part of the first segment.

(75) referred to the pharyngeal plexus as a sort of reflex center which "presides over the operations of the viscera" while the subintestinal cord is locomotor in function. Rorie (110) suggested that the suprapharyngeal ganglion is analogous to the cerebral hemispheres of man, the ventral chain to the sympathetic system and the pharyngeal plexus to the vagus. Chen (21) made careful dissections of the finer branches of

this plexus in *Lumbricus*. He supported Quatrefages by saying that the plexus arises as a chain of nerve cells from six nerves from each pharyngeal commissure from this chain anterior and posterior nerve trunks branch and anastomose freely around the pharynx.

It may be concluded from this discussion that different species of earthworms differ somewhat in the distribution of nerves, but that, in general, each segmental ganglion gives rise to three pairs of lateral nerves, that the brain supplies the prostomium and part of the first segment, that the pharyngeal commissures give rise to a pair of nerves to the first segment and to six pairs of small nerves which join a pharyngeal plexus, and that nerves from the subpharyngeal ganglion innervate the second, third, and fourth segments.

HISTOLOGY OF THE CENTRAL NERVOUS SYSTEM

Most of the early morphologists mentioned in the preceding section observed that the brain and nerve cord of the earthworm consist essentially of a sheath, an outer layer of globules (nerve cells), and an inner mass of tubes (nerve fibers), and that these structures are arranged symmetrically right and left. The study of these details of the nervous system of the earthworm contributed to at least five problems of general interest: the number of processes in neurones, the origin of nerve fibers, the manner of connection between neurones, the paths followed by nerve fibers in the ganglia, and the finer structure of nerve cells. The first two of these may be considered as settled, the others as not yet settled. They can best be understood by a study of the manner of development of each problem.

One of the first problems to attract histologists to earthworms concerned the number of processes in the nerve cells. These cells were first studied in untreated macera-

tions of the nerve cord, then after treatment with various acids, both inorganic and organic. In 1856 Faivre (30) concluded from such preparations, treated and untreated, that there are apolar, unipolar, bipolar and multipolar nerve cells. In 1863 Rorie (110) studied untreated preparations with the aid of a very bright light and reached essentially the same conclusions as Faivre. He added the observation that multipolar cells in the brain give rise to the fibers of the transverse commissure which connects the two lobes of the brain. In the same year Walter (133) treated the nerve cord with acid and observed two lateral groups of unipolar and a central group of multipolar cells. Claparède (22) and Nansen (89 and 90) used a variety of fixatives; they doubted the existence of multipolar cells. The latter maintained that all ganglion cells are really unipolar, the shorter branches being protoplasmic and nutritive.

The problem was ultimately settled by Cajal (18) and Boulé (9 and 10) who used elaborate methods of silver impregnation rather than the less specific fixatives and stains used by the earlier investigators. They demonstrated that the apolar cells in the nerve cord of *Lumbricus* are neuroglia and not true nerve cells, and that most of the nerve cells are unipolar or multipolar; a few are bipolar.

This discussion concerning the number of processes in the ganglion cells led to a study of the origin of the nerve processes. This was studied more intensively in other invertebrates, and the earthworm contributed only incidentally to the solution of the problem. The early histologists agreed that the "Punksubstanz" of the neuropile is fibrous in nature. Vignal (132), among others, contended that some of these fibers are independent, while others, for example Faivre (30), said that they are connected with nerve cells.

Walter (133) and Nansen (90) said that both views are correct. The enunciation of the neurone theory by Waldeyer in 1891 and the use of methylene blue and the Golgi method of nerve impregnation enabled Retzius (107) to show conclusively that all nerve fibers are connected with nerve cells.

Another controversy ensued concerning the connections between neurones in the central nervous system of the earthworm. Vignal (132) in a general review in 1883 postulated anastomoses of processes in the ventral nerve cord as did Walter (133). Nansen (89 and 90) and Retzius (107), however, opposed this view and maintained that true fusion does not occur between nerve fibers, but that the fibers merely come into close contact with each other. In 1897 Apathy (2) contended, on the basis of methylene blue preparations, that in the nerve cords of the leech and earthworm anastomoses occur between the fibers and among the primitive "fibrils" in the nerve cells. Apathy's conclusions with respect to fusion of fibers were not accepted by Lenhossék (77), Cajal (18), Boulé (9 and 10), and Schneider (112), who worked with silver methods. No recent investigators have dealt with this question in the earthworm, but the bulk of evidence obtained with other animals as well as the work of the investigators just mentioned favors synaptic contact and not fusion of nerve fibers in the neuropile of the central nervous system.

The study of the manner of connection among the nerve fibers led to a study of the course of neurones in the ganglia of the earthworm. The paths of many neurones were traced by Haller (43 and 44), Cerfontaine (20), Retzius (107), and Krawany (71), each of whom used specific nerve stains. These histologists agreed that in the ganglia commissural cells connect sensory with motor neurones and that

they connect either the two sides of the same ganglion or two consecutive ganglia. They said that the connection between two ganglia may be homolateral or crossed, and that more motor processes than sensory processes cross from one side to the other. Fortuyn (33) constructed diagrams of the paths of neurones on the basis of the descriptions by these histologists. These diagrams indicate extreme differences in the views held concerning details of the neurone paths. Figure 2 is a series of similar diagrams in which each type of commissural and motor neurone figured by these histologists is schematically presented. These diagrams show twenty-two types of motor neurone and twenty-three types of strictly commissural neurone. Of all these, the main axones of twenty-three are homolateral, and of twenty-two are contralateral. Not a single type of neurone was figured by all four histologists; three types of neuron were figured by three of them; thirteen types were figured by two. This diversity of opinion may be explained by the fact that some neurones and some axone branches are not made visible by these methods and by the fact that each ganglion of the cord contains approximately 120 to 150 cells (Stephenson, 121) of which only a small portion were mapped by any one investigator.

Ogawa (94 and 95) and Tuge (127) estimated the number of cells and fibers in the ganglia of *Perichaeta* and *Allolobophora* and concluded that in the neuropile there are approximately twice as many fibers as there are cells in each ganglion.

Smallwood (118) recently emphasized the extensive branching of central neurones. He and Rogers (109) drew the conclusion that numerous cells participate in even the simplest reactions and that the two-cell reflex is probably not the dominant pattern.

The structure of the individual nerve

cells has been studied fully as extensively as the nature of connections between cells and with equally divergent results. Faivre (30) asserted that the untreated nerve cells are fluid in content. He pointed out that most of the fibers are non-medullated. Vignal (132), Walter (133), and Horst (59) applied acid fixatives to the nerve cord. Vignal contended that the cells are granular. Walter and Horst said that they are fibrillar. Approximately twenty years after Horst's paper the structure of ganglion cells was studied

contended that the motor fibers contain few large fibrils and that the sensory fibers contain many fine ones. Bialowska and Kulikowska (6) described a fibrillar Golgi-Kopsch apparatus among the neurofibrils in the cell bodies of the ventral nerve cord of *Lumbricus*. These observations of anastomosing neurofibrillar nets were made entirely on fixed and stained or impregnated tissues, not on living cells. In the light of recent evidence (Bozler, 15) that anastomoses among fibrils are not seen in living nerve cells and the in-

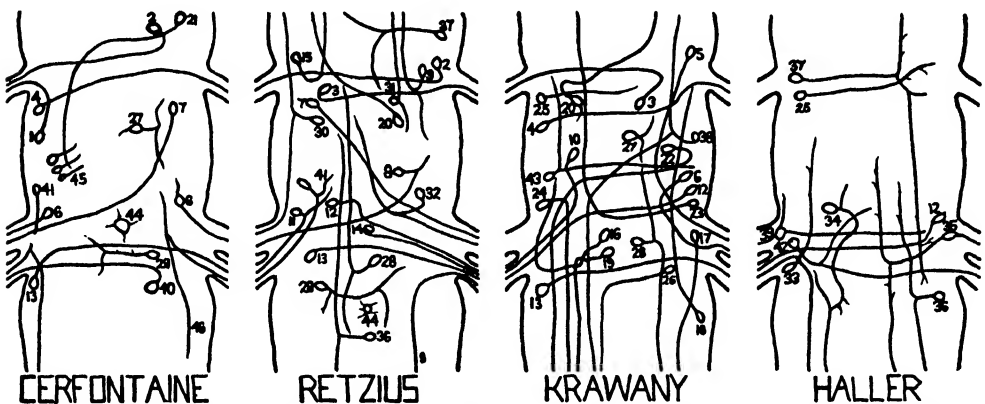


FIG. 2. DIAGRAMS OF TYPES OF MOTOR AND COMMISSURAL NEURONES IN ONE GANGLION OF THE NERVE CORD TO SHOW PATHS OF PRINCIPAL AXONES

Figures condensed from those by Cerfontaine (20), Retzius (107), Krawany (71), and Haller (44). The main axones of neurones 1-4 leave cord by segmental nerve I, neurones 5-8 by nerve II, neurones 9-14 by nerve III, axones of neurones 15-26 pass in anterior or posterior direction, neurones 27-45 are compound in their branches, neurone 46 is sensory. Neurones which were originally shown on both sides of a ganglion are here shown on only one side.

with the aid of the newer silver and methylene blue methods. These methods were used in investigating nerve cell structure in the earthworm by Pflücke (99), Cajal (18), Boulé (9, 10, and 11), Kowalski (69), and Szüts (125 and 126). They maintained that they observed nets of anastomosing fibrils in the cell bodies. Boulé figured an eccentric nucleus and two fibrillar nets, inner and outer; he said that these nets are continuous with the fibrils in the nerve processes. Schneider (112), using a variety of methods,

creasing recognition of artifacts of fixation, a reinvestigation of this question might give important results.

Two other problems, less controversial than the preceding ones, are important in the histology of the central nervous system of the earthworm. These concern the giant fibers and the non-nervous constituents. In the dorsal part of the nerve cord of most earthworms there are three giant nerve fibers. These were first described in 1862 by Leydig (79 and 80). He traced them to the base of the pharynx-

geal commissures and said that they blacken with osmic acid like myelinated vertebrate fibers but unlike other fibers of the earthworm cord. Later (81), he figured an outer clear zone and an inner fibrillar region in these fibers and asserted that they function in the transmission of impulses. Claparède (22) stated that, of the three giant fibers in *Lumbricus*, the median one extends forward farther than the two lateral ones. Horst (59) contended that the giant fibers have a homogeneous fluid content. The giant fibers of the earthworm were studied with the aid of specific nerve stains and impregnations by Friedländer (34 and 36), Cerfontaine (20) and Hönig (58). Friedländer and Hönig said that each giant fiber has its cell body in the posterior ganglion. Cerfontaine agreed with respect to the lateral giants but maintained that the median one arises from a cell in the anterior ventral ganglion. Keyl (66) asserted that there are two branches from the median and three from each lateral giant fiber in each segment; he traced some of these branches to large nerve cells in the ventral part of the cord.

In 1926 Stough (122) made a very intensive study of the giant fibers in *Lumbricus*. He traced connections from the median giants to two pairs and from each lateral giant fiber to one pair of giant cells and to several smaller ones in each segment. Stough stated that each giant fiber consists of compressed axones and that the diameter of each giant fiber is not constant throughout its length. He found two ventral giant fibers in addition to three dorsal ones and maintained that in each segment there is in the giant fibers an oblique partition continuous with their myelin, on the two sides of which the fibers stain differently. He suggested that these septa might constitute a sort of synapse. Smallwood and Holmes (119)

confirmed Stough's conclusions concerning the ventral giant fibers and traced fibrils out to the neuropile, from one lateral giant fiber to another, and from each giant fiber to cells in each segment in *Lumbricus* and *Eisenia*. The preceding evidence indicates that the earlier investigators found only the cells in the posterior and anterior ganglia connected with the giant fibers, whereas these fibers actually give off branches to cells in each ganglion. This evidence also indicates that the connections of the giant fibers both with the neuropile and with each other are relatively abundant.

The non-nervous constituents of the central nervous system remain to be considered. Many of the early investigators observed apolar cells which they assumed to be nerve cells but which were in reality neuroglia. Glial cells in the earthworm were first described by Walter (133) and Claparède (22). The latter observed that they are present not only in the central nervous system but also around the lateral nerves. Claparède also described three sheaths of the cord, an outer neurilemma, a median muscular layer, and an inner neurilemma. Joseph (64 and 65) described the neuroglia in several groups of invertebrates and maintained that they are fibrous in structure. Cajal (18), Schneider (112), Boulé (11), Comes (24), and Havet (47) extended and supported these studies of the sheath and neuroglia. Havet, by means of a gold chloride technique, observed that the neuroglia may be either fibrous or granular and that they are intimately connected with both nerves and blood-vessels. Stough (122) and Holmes (56) described supporting tissue between and around the giant fibers. Holmes maintained that the sheath of the lateral nerves differs from that of the ganglia only in its lack of muscle cells.

The above account indicates that the

earthworm contributed to the general conclusions that central nerve cells may be unipolar, bipolar, or multipolar, and that all fibers originate in cell bodies. It also indicates that, although much knowledge is available concerning the neurone paths, the fibrillar structure of nerve cells, the nature of the giant fibers and of the neuroglia and sheath of the central nervous system of the earthworm, many histological problems remain unsettled. For example, the function of different types of neurone as indicated by the course of the processes of these cells is largely unknown. The nature of the fibrillar network in the cells and its relation to the fibrils of the axones remain undetermined, as does the nature of the contact between fibers in the neuropile and in the giant fiber tracts. The relation between the small axones of the giant fibers and the giant cells and the branches between the fibers remains to be settled.

PERIPHERAL COMPONENTS OF THE NERVOUS SYSTEM

In addition to these central elements, two peripheral components of the nervous system, the peripheral network or plexus, and the sensory cells, may be considered. Retzius (107), Smirnow (120), and Langdon (73) maintained that there is a network of nerve fibers beneath the epithelium. Smirnow added that the blood vessels also are covered by such a network. Kolmer (68) figured fibrils passing from the epithelial sensory cells of *Lumbricus* into the subepithelial plexus. Dechant (28) confirmed these findings, stated that nerve cells as well as fibers are present in the plexus, and that a similar subepithelial plexus exists in the pharynx. Hess (51 and 52) showed that the network occupies an intermediate position between the sensory cells and the central nervous system and found continuity between sub-

epidermal and intermuscular plexi. Smallwood (115, 116, and 117) found a nerve network in these regions and also on the blood vessels, septa, nephridia, and digestive tract. He contended that the sensory nerves do not contain so many fibers as there are sensory cells; hence convergence of fibers from the sensory cells must occur in the subepithelial plexus.

Dechant, Hess, and Smallwood used a variety of methods and maintained that the peripheral plexus is a true net of anastomosing fibers. Langdon found no such continuity. The other histologists were largely non-committal on this point. The question of whether the peripheral plexus is a true net remains unsettled. In fact, the existence of any true peripheral net is debatable. As opposed to a network, Bozler (15) found discontinuous synapses in coelenterates. Numerous neuro-histologists have cast doubt upon the validity of the silver methods for distinguishing contact from continuity of fibers. Physiological evidence will be presented below against the existence of a true net in the earthworm.

Knob-like nerve endings among the muscles were described by Retzius (107), and branching nerve endings by Smallwood (117). It is likely that these are motor endings.

Dawson (27) found nerve cells in *Lumbricus* among the muscles and on the nerve rings, particularly where the segmental nerves branch. He asserted that these cells may be sensory in nature, probably proprioceptive. The same sort of nerve cell among the muscles and between the epidermis and muscles was described later in *Pheretima* and *Eisenia* by Zyeng (138).

Epithelial cells, supposed to be sensory in nature, are considered by numerous investigators. Mojsisovics (84), Horst

(60), Ude (128), Vejdovsky (131), Cerfontaine (19), and Lenhossék (77) described epidermal cells which bear hairs at their peripheral ends and are frequently found in small groups about a pore canal. They are connected centrally to fibers which pass to the central nervous system and are undoubtedly sensory.

In 1895 Langdon (73 and 74) maintained that thirty or more of these sensory cells, each with a terminal hair, constitute a sense organ and that each cell gives rise to a nerve fiber proximally. She found an anterior, median, and posterior zone of these sense organs in each segment and contended that they are most numerous in the anterior, less numerous in the posterior, and least in the middle regions of the body. Havet (46) described the sensory cells in the epidermis of the earthworm as pyramidal, pyriform, fusiform, or moniliform.

Smirnow (120), Retzius (108), and Langdon (73) found free endings of sensory nerve fibers among the epidermal cells.

Hesse (54 and 55) found these sense organs in the epidermis and also other sensory cells of a more specialized sort in the epidermis, in peripheral ganglionic masses in the prostomium and first segment, and sometimes near the surface of the brain. These cells, he said, have a clear cytoplasm and a large well-differentiated body which he called a "Binnenkörper." Their shape, distribution, and abundance vary among different species. He found these particular cells to be most abundant in the regions which are most sensitive to light, and called them "Lichtzellen" or photoreceptors. Kowalsky (70) and Hess (53) further described the "Lichtzellen" of Hesse. Hess found in 1925, by means of silver impregnations that the "Binnenkörper" and the rest of the cytoplasm contained numerous anastomosing neurofibrils and that part of the

former body focuses light on the fibrillar net. It is assumed that all of the other epithelial cells and organs are sensitive to tactile or chemical stimulation, but no definite information concerning their sensitivity is available, hence strict proof that these cells are sensory in nature is lacking.

REGENERATION

Earthworms have frequently been used in the study of regeneration of nervous tissue. Early observers, Bonnet, Spallanzani, and others, reported instances of regeneration of lost parts, but this was denied in the earthworm by Williams (134) as late as 1851. Newport (91) in 1855 exhibited three worms in which more than a third of the posterior part of the body had regenerated.

Heschler (49) stated that, when a number of segments are removed, cells are pushed out from the old nerve cord and that the brain can be regenerated from epithelial cells. Rand (105, 106) claimed that both the brain and the ventral nerve cord of a regenerating region come chiefly from epithelium, but that undifferentiated cells in the ganglia may become nerve cells. Hall (42) maintained that ventral nerve cells may migrate into a cut region of the nerve cord. Nuzum and Rand (93) stated that even new pharyngeal epithelium can contribute to a regenerating brain. Schwartz (113), using the Nissl technique, claimed to find that connective tissue is transformed into nerve cells. Thus three tissues have been stated to give rise to regenerating nerve cells. It is difficult to believe that connective tissue of mesodermal origin can contribute to nerve cells. In fact, the problem is far from settled.

Morgan (86), Hunt (61), Siegmund (114), and Bailey (3) said that the presence

of a free cut end of the ventral nerve cord is necessary for regeneration. Goldfarb (40) maintained that it is not necessary. Bailey (3) asserted that if the free end of the nerve cord is folded back on the cord leaving several segments without any connection with the central nervous system after part of the body is removed, usually no nervous tissue and sometimes no new head or tail is regenerated. Kropp (72) recently found that when a brain from another worm is transferred to the dorsal region of a regenerating anterior end, the brain is resorbed, but when transplanted to the ventral region, it is incorporated into the new subpharyngeal ganglion. The cut end of the nerve cord, therefore, appears to be a center of regeneration.

THE FUNCTION OF THE NERVOUS SYSTEM

One of the most interesting problems in the physiology of the nervous system of the earthworm concerns the functions of the central nervous system and the peripheral plexus in conduction of impulses in locomotion. Physiological studies have also contributed to the problems of the nature of locomotor peristalsis, segmental independence, the function of giant fibers, and cephalic dominance.

Fundamental work was done on the first of these problems by Friedländer (35 and 37) who removed the ventral nerve cord from several segments of an earthworm. He observed a flaccid condition in the muscles of these segments and stated that when a locomotor peristaltic wave passes backward, there is no contraction in the denervated segments except as they are pulled out by the contracting anterior ones. He said that this region pulls like a loose string on the segments behind it, and that these segments then begin active contraction apparently coordinated with the anterior region. He then tied the two halves of a

transected earthworm together with a thread and observed similar coordination between them. He also observed that tactile stimulation of the posterior segments initiated a forward moving wave which stopped at the segments lacking the nerve cord. He concluded that the mechanical effect of the pull of one region upon another and traction upon the substratum initiate peristalsis. He postulated a reciprocal reflex of "thickening" and "thinning" which involves alternate contraction and relaxation of the two sets of muscles and the intermediation of the ventral ganglia as reflex centers.

These results were confirmed by Maxwell (83), Biedermann (7), and Morgulis (87). Maxwell stated that the coordination observed in *Lumbricus* after the cord is transected does not occur in the polychaete, *Nereis*. Biedermann emphasized the loss of tonus in segments lacking the nerve cord. Moore (85) and Garrey and Moore (39) experimentally supported Friedländer's theory of the origin of the peristaltic contractions. Moore elicited peristalsis by hanging weights to a suspended earthworm in which the epidermal receptors had been anaesthetized. Garrey and Moore stroked preparations of earthworms, which were held by clamps to minimize tension, with a brush and maintained that peristaltic waves are induced by backward strokes but are inhibited by forward strokes. They concluded that contact with the substratum as well as tension from segment to segment is of importance in initiating peristalsis. They stated, however, that in these clamped specimens coordinated waves cease when the nerve cord is cut and that the type of response varies with the direction of propagation of the impulse in the nerve cord. Knowlton and Moore (67) further developed the idea of reciprocal innervation of the two muscle layers which

plexus except that it does not function as a true net in the coordination of peristaltic movement and in epithelial secretion. It probably functions, as Smallwood (117) suggested, as a center of branching of processes to the sensory cells.

The study of the earthworm has also contributed to the problem of segmental independence. In 1897 Maxwell (83) observed a lack of tonus in segments from which the ganglia had been removed and suggested that each ganglion is a local motor center for its particular segment. The importance of tonus as controlled by the ganglia was emphasized in a discussion of crawling by Van Essen (130). Several investigators, Friedländer (35 and 37), and Knowlton and Moore (67) developed the idea of reciprocal contraction of longitudinal and circular muscles in crawling, and Buddenbrock (16) postulated a bisegmental reflex involving two consecutive ganglia to account for this movement.

Janzen (63), by a series of operations, obtained evidence that each ganglion is a reflex center for the antagonistic contraction of the two muscle layers and for the movement of the setae in any given segment. He asserted, however, that the reflexes of any particular segment are coordinated with those of the segments immediately anterior and posterior to it and that the control is usually homolateral, but that impulses can cross from side to side. It may be concluded from this evidence concerning ganglionic effects on tonus and on segmental reflexes that each segment is essentially an equipotential but not an independent unit.

The results obtained in observations on the rate of conduction in the nerve cord differ considerably. Bovard (12) by means of myographs ascertained the rate of conduction in the motor fibers of the cord to be approximately 0.025 m. per

second and that in the giant fibers to be approximately 1.25 m. per second. Lapique and Veil (76) by the same method found conduction in the ventral nerve cord at the rate of 0.6 m. per second, and in the muscles at 0.35 m. per second. More recently Eccles, Granit and Young (29) measured the conduction rate in the giant fibers by means of action potentials. They found two groups of impulses, one at the rate of 17 to 25 m. per second and the other at 0.7 to 1.2 m. per second.

Conduction in the giant fibers differs from that in the rest of the nerve cord. When strongly stimulated, earthworms swing the two ends together in a sort of coil and then apart vigorously. Friedländer (37) suggested that, since these quick end-to-end contractions are lacking when the cord is cut, the control of such contractions is the function of the giant fibers. Rabes (104), however, claimed that end-to-end contractions can occur before regeneration of the giants is complete. Bovard (14) found that when the cord is transected, the giant fibers regenerate later than the fibers concerned with normal locomotion and that the action of the giants can be stopped by stavaine without affecting that of the bulk of the fibers in the cord. He concluded that the giant fibers are not associated with normal locomotion but with rapid impulses involved in responses of the entire animal. Yolton (137) cut the dorsal giant fibers while the rest of the cord was left intact and found a loss of these quick end-to-end contractions. Single giant fibers were cut by Stough (123) who maintained that the median dorsal giant fiber of *Lumbricus* conducts postero-anteriorly while the two lateral ones conduct antero-posteriorly. Eccles, Granit, and Young (29) studied the action potentials in the giants instead of muscular activity. They disagreed with Stough by stating that these fibers

can conduct in either direction and that apparently the slow impulse mentioned above travels in the lateral fibers and the fast one in the median giant fiber. Prosser (100) found that in embryos of *Eisenia*, the end-to-end contractions do not appear until after a giant fiber is differentiated. It may be concluded that the giant fibers conduct rapid impulses which are involved in rapid contraction of both ends of the earthworm. Whether they are polarized or not requires further investigation.

The problem of cephalic dominance is also of importance in the physiology of the nervous system of the earthworm. Histological as well as functional evidence indicates that the ventral nerve cord is largely motor and the brain sensory in function. Janzen (63) claimed that removal of the cerebral ganglion interferes very little, if at all, with most motor activities, but that motor centers exist in the ventral ganglia, their effect being strongest in the subpharyngeal ganglion and decreasing posteriorly. He says, for example, that behavior when the anterior end is hung over the edge of a plate is largely controlled by the subpharyngeal ganglion.

Friedländer (37) found that brainless worms are restless and active, that they crumple the anterior tip, burrow very reluctantly, but enter into coitus, and crawl normally. Yerkes (136) and Heck (48) taught earthworms to run simple "T" mazes. They found that when the first four segments were removed, the ability to run the maze was retained. Focke (32) said that when the brain is removed, an earthworm swings its head about more than usually, turns over normally when placed on its dorsal side, and burrows into the substratum but requires thirty minutes to burrow as contrasted with two minutes normally. These effects indicate slight sensory defi-

ciency resulting from loss of the brain and no interference with motor activity.

The effect of the brain on responses to light has been more thoroughly investigated. Graber (41), Loeb (82), and Hesse (55) stated that when the anterior four or five segments are removed, earthworms aggregate in the dark regions of a box nearly as frequently as do normal worms. In 1924 Hess (50) maintained that when the brain is removed from *Lumbricus* the responses to light of moderate intensity are reversed from negative to positive. Nomura (92) obtained similar results with *Eisenia*. Prosser (101) found that separation of the two lobes has nearly the same effect upon responses to light in *Eisenia* as does removal of the brain, and that subjection to low temperatures or injection of depressant drugs over the brain also have essentially the same effect. He concluded that normally the tracts involved in this response cross from one side of the brain to the other and that this crossing-over may explain the reversal on removal of the transverse tracts.

It may be concluded that physiological studies of the nervous system of the earthworm do not completely support the conclusions concerning function drawn from morphological observations. The functions of the peripheral plexus are still uncertain, although it is probably largely sensory in nature. Physiological evidence does not support the idea that the subepidermal plexus is a non-polarized nerve net. The evidence of Eccles, Granit and Young concerning rapid conduction in both directions in the giant fibers does not support Stough's conception of segmental synapses in them. It is certain that the ventral ganglia are largely motor and the brain is almost entirely sensory, but quantitative measurements of such effects are entirely lacking. It has been demonstrated that there is antagonism

between circular and longitudinal muscles, but very little is known concerning the mechanism involved.

In conclusion, although the earthworm has contributed to many problems of invertebrate neurology, at least three general problems have been treated more conclusively in the earthworm than in other animals. It was stated above that most of the histological evidence indicates that the peripheral plexus of the earthworm is a true nerve net with continuity of fibers. The functional evidence, however, strongly indicates that the peripheral plexus does not function as a non-polarized net, at least not with respect to the impulses involved in epithelial secretion and in coordinated muscular contraction. Thus, the nerve cord is essential to normal locomotion, and Friedländer is fully supported in his postulate of reciprocal reflex contractions of both muscle layers resulting from stimulation by tension and contact. On the other hand, some reactions appear to be under peripheral control. The importance of peripheral receptors is indicated by co-ordination anterior and posterior to a region lacking the nerve cord and by the responses of muscle-skin preparations. It is probable that these peripheral receptors are connected with the muscles both by fibers originating in the peripheral plexus and by others from the segmental nerves. It appears, therefore, that the earthworm falls between the polychaetes, in which the central nervous system controls peristaltic contractions, and the flatworms,

in which peripheral elements are more important.

The earthworm has contributed more than other forms to a second important problem,—the structure and function of the giant fibers. According to the above evidence these fibers are unlike most others structurally and functionally. These big myelinated bundles of axones have abundant connections with cells, with the neuropile, and with each other. They conduct rapid impulses involved in defensive reactions of the entire animal, and there is coordination not only throughout each giant trunk but also between the two lateral fibers. Apparently these giant fibers lack the segmental independence of most neurones of the cord, yet segmental septa indicate that each fiber is not one long axone extending the entire length of the worm. The function of these segmental septa is an important problem for the future.

The earthworm is one of the simplest forms in which cephalic dominance in the central nervous system has been clearly demonstrated. The distribution of nerves in the anterior segments indicates fusion of the ganglia of the first three segments. The subpharyngeal ganglion is important in regulating the motor activities of the rest of the cord. The brain is a sensory center and controls some types of behavior of the earthworm such as the responses to light.

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THE HABITS AND CHARACTERISTICS OF NOCTURNAL ANIMALS

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A CONSIDERATION of problems associated with the nocturnal activity of animals tends to become as complicated as it is interesting. The contributions of several branches of biological investigation must be drawn together before even a fairly complete picture appears. This discussion of the conditions of life at night, the possible advantages of the nocturnal habit, and the usefulness at night of the several senses follows records of the writer ('31, '32, '33), Park, *et al.* ('31, '32) and many others on the nocturnal and crepuscular activity of various animals. In the interest of brevity references are cited only in connection with newer, more controversial or more significant phases of the discussion. In general, the study is limited to a consideration of the arthropods and land vertebrates, although some other references are made.

A. ENVIRONMENTAL FACTORS

Park and his colleagues ('31) determined for several Ohio insects of climax forests, that for the species studied, and within the limits of the ranges of the factors observed, nocturnal activity tended to increase with the increase of relative humidity, decrease of air temperature and rate of evaporation. Conversely, nocturnal activity tended to decrease with decreased relative humidity, increase of air temperature and rate of evaporation. Similarly Necheles ('27) reports that the only factor which has any appreciable influence on the nocturnal activity of

certain cockroaches and mosquitoes is air humidity, as influenced by temperature, and its effect on the rate of water loss by these insects. The value of increased humidity to nocturnal animals receives comment below. Nevertheless, at least for vertebrate animals the absence of light looms as the most characteristic factor of the nocturnal environment.

The influence of light is apparent in most animal forms. Diurnal insects accustomed to sleep at night are less active or are quiescent on cloudy days. Conversely, nocturnal forms shun the light. Moonlight tends to enliven diurnal forms at night to some extent. Thus, we have the calling of day birds and the voicing of some primarily daytime mammals at night. The phenomenon of phototropism is quite familiar. Most butterflies are attuned to a high intensity of light, many moths to a low intensity, so that bright sunlight, which calls forth the one, causes the other to retreat; and on the other hand a light like that of the candle, so weak as not to stimulate a butterfly, produces a marked response in the moth. Rau ('29, '32) reports for saturniid moths and two firefly species that normal activity is brought about by certain intensities of light, and that these animals respond at other than the usual times if the optimum light conditions are simulated. *Samia cecropia* is reported to fly regularly during the hour just before and during the period of dawn; *Platysamia cyntbia* and *Telega polyphemus* to have a period of flight in the hours before midnight and another at

dawn; *Callosamia promethea* to fly in the late afternoon. *Photinus pyralis* is reported to fly early and in low flight, *Photuris pennsylvanica* to fly only after dark and at higher levels. Allard ('31) notes that the general trend of the curve of relative humidity may be accidentally associated with that of the sunset curve. He believes the activity of fireflies to be determined by a more or less specific level of light intensity operating through the visual sense.

B. POSSIBLE ADVANTAGES OF THE NOCTURNAL HABIT

In considering the reason for the activity of certain forms at night while the greater part of the animal world sleeps, there appear certain probable advantages which may or may not constitute sufficient reasons for the adoption of the nocturnal habit. It would not be supposed that, except in the higher mammals, the night time is consciously chosen on account of any of these advantages. It might be considered that these benefits associated with nocturnal activity were factors that in some way and over a long period of time made these various races nocturnal in habit. Now inherent in these forms of life, the propensity for nocturnal activity expresses itself when the stimuli of nocturnal factors recur in nightly rhythm. However, some animals show a recurring nocturnal-diurnal rhythm when they are kept in the laboratory under constant conditions of illumination, humidity and temperature (Welsh, '30b; Park and Keller, '32).

The most evident advantages of the nocturnal habit are:

1. Avoidance of natural enemies active in daylight

Thus, many spiders seek seclusion during the day, when they are the likely fare

of reptiles and birds, and sought by many Hymenoptera. Millipedes and centipedes are eaten by various birds and reptiles. Mantids and walking-sticks are the food of lizards and birds, although they are seemingly protected in both color and form. Even roaches are eaten by daytime birds. Toads and frogs are eaten by hawks and snakes. Harvestmen, crickets, certain beetles, many moths, certain ants, various bats, rats and mice are other forms which may find activity at night a means of avoiding many daytime enemies.

There is greater safety at night for the uninterrupted feeding of herbivorous animals, such as fruitbats, capybaras, agoutis, rabbits, sloths, deer, moose and tapir. Animals engaged in feeding activities are apt to be especially vulnerable to their natural enemies.

2. Easier acquirement of the preferred food at night

This may be due to the invisibility of the hunter, the plentifulness at night of the intended prey, or the greater ease of detecting victims by the sense of smell. Odors remain longer in the air at night, due to greater humidity, and the relative absence of upward air currents. Further, if the prospective victims are themselves typically diurnal, they are more vulnerable at night on account of sleep or its equivalent, or their poorer adaptation for successful nocturnal activity. Such an advantage may be realized by carnivorous animals, including scorpions, spiders, tarantulas, centipedes, and among the vertebrates, alligators, boas, anacondas, pit-vipers, owls, most bats, raccoons and the various cats.

Scavengers and general feeders may be able to find food with more ease at night, due to better conditions for the use of the olfactory sense. Here might be listed the millipedes, roaches, many beetles, and the

vertebrate opossums, kinkajous, and armadillos.

3. *Avoidance of excessive evaporation from the body*

The atmosphere is at night as a rule cooler and damper than in the daytime. Animals that from the nature of their external covering would suffer from excessive evaporation through daytime activity, and would conceivably benefit from the nocturnal habit include earthworms, snails, *Peripatus*, cockroaches, mosquitoes, termites, toads and treefrogs. Thus Necheles ('27) reports that mosquitoes seem to prefer a relative humidity of 75 to 85 per cent, and that they retire during the day to avoid the excessive evaporating influence of daytime air with its low humidity and higher temperature.

4. *Easier communication at night*

Sounds produced have less competition, odors travel farther and are apparently stronger in the damp air. Photogenic organs are of value at night and useless by day. These advantages will be discussed under the heading "Usefulness of the several senses at night."

Some forms seem to benefit in two or three of these ways. In any one species, the reasons applicable can only be conjectured. Not all of the animals active at night can be seriously placed under any heading. Thus the fact that the long-horn grasshoppers are in some species nocturnal, in some diurnal, while practically all are apparently protectively colored and all face the same conditions, is difficult to explain. Along with almost any form active at night for any apparent reason, can be found a closely related form not active at night, yet exposed to the same conditions. The problem is hence a very complex one.

C. USEFULNESS OF THE SEVERAL SENSES AT NIGHT

When we seek to determine the adaptations exhibited by forms active at night, we encounter again much uncertainty. Such differences in sense organs as exist between nocturnal and diurnal forms of close relationship are differences of degree rather than of kind. There are a few definite adaptations in the way of light, sound and scent production. Nevertheless, with the possible exceptions of luminescence and some adaptations of vision, there is observed no modification which might not be fully as useful by day as by night. Our judgment is that the extreme development of some of these specializations of form and function is not so necessary by day as by night. The species described might be capable of successful nocturnal existence without any or all of the unusual modifications which they exhibit. The crucial point of development of each sense necessary for the successful nocturnal activity of each animal would be very difficult to determine, especially since the senses are not employed singly so often as collectively.

It would be difficult to tabulate in exactly certain order the relative usefulness of the various senses at night. The sense of smell is probably of greatest importance, and that of sight might be named last, but this arrangement would be questioned. It must be remembered that our ideas in regard to the sensations of animals other than ourselves, of invertebrates certainly, are only inferences from our own sensory experiences, and hence doubtless often inadequate and erroneous. We can never be sure that lower animals experience sensations in the same way that we do, even if the necessary receptor organs seem to exist.

1. *The sense of smell*

For purposes of communicating through this sense, it would be expected that the odors perceived by some individuals would be produced by others. Many such organs of scent production are known and there are undoubtedly many yet to be discovered. Numerous nocturnal animals have the necessary equipment. Harvestmen have scent glands near the anterior margin of the cephalothorax. In millipedes scent glands are present on various body segments. Walking-sticks have thoracic scent glands, used primarily for defense. The roaches have scent glands in certain abdominal segments, and give off a discernible fetid odor. Odor plays a very prominent part in the organization of termite colonies. In moths, glandular scales producing odor occur on the wings of various species, and at least in some groups the females possess a paired scent organ in the last abdominal segment. Army ants have a strong odor on which the organization of the colony depends heavily. The odor is produced by the pulvinate glands of the poison apparatus. Odors are also given off by the bugs and fireflies. Alligators produce musk from skin glands beneath the chin. Mammals yielding scent include the raccoon, skunk, porcupine, the cats, peccaries, muskrats, deer, elk, armadillos, and others. It will be noted that in addition to its usefulness in communication, scent production may be of value in defense, and in making the producing organism unpalatable to its enemies.

There is a wide variety of receptor mechanisms. Although spiders seem to have a well-developed sense of smell, the receptors apparently have not yet been located, unless certain hairs are olfactory in function, or the "lyriform organs" function in that capacity. However, Baerg ('28) indicates that tarantulas de-

pend entirely on touch to locate food, seemingly placing no dependence on olfactory organs. In crickets the abdominal cerci are probably partly olfactory in function, as they are in roaches. Glaser ('27) shows that chemoreceptors are located also on the antennae of roaches, and that these are effective in detecting odors from a distance. In moths the antennae are probably chiefly olfactory in function and are more developed in the male (Mayer, '00). In Diptera, where the sense is well developed, work of Liebermann ('25) shows a rich supply of olfactory organs on the antennae. Olfactory organs may exist elsewhere than on the antennae. Indeed, McIndoo ('34) reports that in the blowfly the olfactory function is demonstrated by tarsi rather than antennae. Hymenoptera can detect delicate odors. Work of Hauser ('80), von Frisch ('21), Vogel ('23) and Wacker ('25) has designated the antennae as carrying olfactory organs in many species. McIndoo ('14 a, b, c; '16; '20) has reported the sense to be resident in other portions of the body as well. Some beetles (Valentine, '30) also have olfactory organs on the antennae. In other beetles the sense organs seem to be widely scattered over the body (Abbott ('27 a, b), McIndoo ('26)).

There are organs of other types which may be suspected of having an olfactory function, although this may be mixed with other sensations received from the same organs.

The well known nasal olfactory apparatus of the vertebrates needs no comment here.

Since the necessary equipment thus seems to exist in all of these groups, the olfactory sense may be suspected of functioning at night in at least four ways.

a. Congregating of individuals of the same species, and trail-following. Invertebrates

employing the sense for these purposes would include moths, termites and ants. In the last two groups named, the activity of the whole colony is doubtless directed chiefly by scent and odor. Some vertebrates that could be named in this connection are muskrats, beavers, raccoons, cats, porcupines, armadillos, bears and deer.

b. Sex attraction, by means of "alluring glands." Moths, beetles, roaches, walking-sticks and, among the vertebrates, alligators, deer, cats and peccaries would come in this category. The females of many moths and beetles, especially, emit an odor that attracts the males, often in considerable numbers. Sometimes the males also possess such glands.

c. Location of food. Animals in which this may be an important use of the sense are roaches, beetles, moths, mosquitoes, ants, armadillos, bears, porcupines, foxes, weasels, mice, rats, opossums, rabbits, raccoons and many others.

d. Detection of enemies and friends. This is apparently an important use of the sense in many vertebrate forms such as bears, deer, antelope and tapir, such invertebrate groups as the ants and termites, and doubtless many other insects.

2. The sense of taste (closely associated with the olfactory sense)

Among the invertebrates the organs of taste are difficult to demonstrate with certainty. Glaser ('27) reports chemoreceptors on the maxillary and labial palps of roaches. Minnich ('22a, '22b, '26a, '26b, '31) reports taste in the tarsi as well as the mouthparts of the butterfly and of the fly. In the honeybee, he ('32) reports contact chemoreceptors concerned with food choice in the antennae and first pair of legs as well as in the mouth parts. He concludes: "Taking bees, butterflies, and flies collectively, instances of contact

chemoreceptors can be found in all or practically all of the head and thoracic appendages. It is suggested, therefore, that the ancestral insect may have possessed such receptors in each of its appendages." Probably the sense is very generally developed throughout the groups of non-aquatic invertebrates.

No special development of this sense would be expected in nocturnal animals beyond the conditions found among their daytime relatives. Perhaps our ideas on this point do not coincide with the actual situation, however, since the sense is so much more highly developed among many invertebrates than in ourselves, and hence probably much more significant in their lives than in ours. The occurrence of organs of taste in tarsal and antennal structures would seem to give the sense special usefulness at night for finding and inspecting food, if any species possessing such special equipment are active in the dark. Organs of taste certainly have large usefulness at night for inspecting food that cannot be seen.

Perhaps the only possible distinction between the senses of smell and taste is that if these end organs actually come in contact with the food they are considered gustatory; if they do not, they are considered olfactory. Both of these senses, when resident in antennal structures, are closely associated with that of touch, next to be discussed. There would thus be a contact-chemical sense of simple unified character.

Nocturnal arthropods which obviously have very delicate antennae on which they depend heavily for sensory experiences include centipedes, crickets, walking-sticks, roaches, termites, ants, moths, midges and mosquitoes. They are doubtless just as important in other insects whose antennal equipment is not so apparently depended upon.

3. *The sense of touch*

Organs of touch are of value at night in moving about, in inspecting food or other objects encountered, and in perceiving vibrations, this last faculty passing into that of hearing, which will be considered separately. Among the invertebrates many sensitive and elaborate devices for stimulating end organs are found. Delicate tactile hairs are distributed over the body and appendages in many species. The antennae have already received comment.

In the vertebrates, aside from the general sensitivity of the skin, we find such special developments as the vibrissae of rodents and various other mammals, the delicate muzzle of the deer, and the very sensitive organs of the nose and wings of the bat. Lynn ('30) reports that the facial pits of the pit-vipers function in the perception of air vibrations. The pit membrane is a modification of the integument of the head. All of these organs are devices for stimulating nerve terminations.

4. *The thermal sense*

Closely associated with the tactile sense is sensitivity to temperature. Wheeler ('26) notes concerning ants, "that these insects have a delicate temperature sense, although the location and nature of its organs are quite unknown, is shown by many of their habits, notably by the way they regulate their hours of activity. . . ." Temperature, correlated of course with humidity and air movements, doubtless affects the degree of activity of many animal forms. Kennedy ('27) notes that insects, with a large surface-to-volume ratio and coldblooded nature, have a special problem with reference to temperature changes.

5. *The sense of hearing and sound production*

The sense of hearing is closely allied to

that of touch. Sound production and reception is an important means of communication between members of the same species at night, as well as by day, and is important in the detection of approaching enemies or victims, as the case may be. Sound-making serves to frighten away enemies, to warn others of their approach, to attract and woo mates, to communicate general information. Noble ('31) says that "the chief function of the voices of frogs and toads is to attract mates," but lists other possible uses of the voice. Vertebrates apparently depending at least in part on this sense for communication at night include alligators, some geckoes, owls, goat-suckers, shrews, bats, mice, cats, foxes, coyotes, rabbits and hares, howler-monkeys, and many others.

Among invertebrates (both nocturnal and diurnal), sound is produced by stridulating organs or other sound-making devices, through the use of vibratory structures of various types, or the tapping of surrounding objects.

Many spiders have stridulating organs, but the stridulation is not always audible to human ears. These organs occur variously on the mouthparts, or thorax and abdomen. Since no certain auditory apparatus has been discovered in the spiders, it is probable that these stridulatory organs are for giving warning signals to other animals, not for use as means of communication with other spiders. Indirect evidence that spiders can hear is, however, presented by the fact that in certain groups, the males alone have stridulatory organs. Unless the females have auditory powers, this fact is difficult to explain.

Among wood-boring beetles, ticking or clicking serves as a means of communication, and doubtless helps to keep the colony together. Thus *Passalus* beetles have stridulatory organs on the abdomens of adults, on the middle legs of larvae. In

the "death-watch" beetles such ticking is believed to function in attraction of the opposite sex. The tegmina of male "grass hoppers" are furnished with stridulating organs. Auditory tympana are present in the fore tibiae. Male crickets stridulate by means of a file and scraper arrangement on the wings. Crickets have tympana on the fore tibiae, except in a mute wingless species. Mole crickets have tympana in the fore tibiae. The males can produce a dull jarring note. Among crickets and grasshoppers, the females are attracted to the males by their chirping. The synchronous chirping of two or more males seems to show that sound is heard by them as well as by the females. Allard ('28) points out that the stridulation of Orthoptera possesses tonality in the case of the crickets, highly specialized technique and variety among the katydids, and rhythm in both of these groups. Vibration of wing elements is the stridulating device most frequently observed in Orthoptera.

Some moths apparently possess stridulating organs. Wing vibration may function as a means of attracting the opposite sex, but according to the Raus ('29) this assists in the dissemination of the odor which is known to be an effective agent. The vibration may not be attractive in itself.

In mosquitoes the humming of the wings is a means of communication. Some of the delicate fibrillae of the bushy antennae of the male vibrate sympathetically with the wing note of the female. Child ('94) describes an experiment conducted with the aid of a tuning fork and concludes that the vibration of the fibrillae acts upon a complex organ found in the second basal segment of the antenna. As this organ functions only when the hairs are at the proper angle to the sound waves, the male mosquito can perceive not only the sound

but also the direction of it. Buzzing is a means by which female flies attract males.

Some bees doubtless influence others by buzzing. Among ants chordotonal organs may occur in the tibiae of all pairs of legs, at the bases of the antennae, and elsewhere on the body. Ants exhibit varying stridulatory powers.

It must be remembered that many sounds that we cannot hear, because of their being too high or too low in pitch, are produced and heard by other animals. This is especially true of the insects. Further, the kind of sound to which the human mind adjusts itself evidently differs from that which is most significant to the animal. Man is rather little concerned with the sounds and noises which the things themselves produce and which are meaningful for the animal. The sounds which most often concern man are those of organized speech which merely refer to the objects.

6. Light production and the sense of sight

Among arthropods light is produced by fireflies of both sexes and the larvae, the elaters and their larvae, and by numerous other forms (Harvey, '20). The photogenic organs of lampyrids consist of granular cells enclosed in a network of fine tracheae. These cells have the power of secreting a substance which is luminous when acted upon by oxygen from the tracheae in the presence of moisture. Fundamentally, this effect seems to depend upon a luciferin-luciferase reaction (Harvey, '20, '32), although not all luminous animals give the reaction (Harvey, '26). There are various luciferins and luciferases, specific for the forms exhibiting them. These are similar in closely related luminous species, relatively unlike in more distantly related forms. There is a reflecting layer of cells beneath the photogenic cells. The reflecting medium is a white urate,

secreted by the cells of this deeper layer. The mass of branching tracheae makes possible the rapid oxygenation and the resulting flash of the fireflies. Allard ('31) notes that the rate of flashing may be modified by temperature. Light so produced ranges among various animals from green to various shades of red, purple and violet. Several colors may be emitted by different organs on the same animal. Snell ('31), working on *Photuris pennsylvanica*, concluded

that the mechanism controlling the flashing is responsive to nervous and to direct electrical stimulation, that it effects the control by regulating the admission of oxygen to the cells containing the photogenic substances, and that variation in the character of the flash is brought about by variation either of the number of units stimulated or of the amount of stimulation and response (admission of oxygen to the cells) in the unit involved. The tracheal end cell, which has for a long time been considered by histological investigators to be responsible for the control of luminescence, is certainly the responsive mechanism in this control.

There are many gradations in complexity of light organs among various animal species.

Light production has sometimes been considered as simply a by-product of metabolism, but the phenomenon that has been often observed (recently, Morrison, '29; Howard, '29; Merrill, '30; Richmond, '30; Rau, '32) of the synchronous flashing of the fireflies in a given area, would seemingly indicate that the light produced by one is perceived by other individuals, and that they are influenced by it. (However, Rau interprets this as being originally a simultaneous response of individuals to a sudden environmental change, followed by accidental flashing in unison until they "break step.") The flashing of fireflies has also been observed to have a part in sex attraction (McDermott, '12; Mast, '12). The luminous "eyes" of adult elaters are thought by some to be of "horrifying" or

warning intent. Harvey ('20) writes that some animals possess a periodicity of luminescence. They only luminesce at night and are difficult to stimulate during the day. Further, these animals are negatively heliotropic to a very strong extent, and lie hidden during daylight.

The opportunity for the employment of the sense of sight at night is quite limited compared to its daytime importance. However, some animals can apparently see quite well, even when there is no moon. That eyes are subject to adaptation is eloquently testified by the fact that cave animals have degenerate eyes or are eyeless.

Concerning visual cells in general, it is evident that eyes may perform three functions, to determine the intensity of light, to perceive the direction of illumination, or to record light-images of the objects from which the rays come. Some eyes have all three functions. The body surface of some animals contains other light-sensitive cells than those in the eyes, and these can perceive light and even its direction. If deprived of its eyes, a frog can still orient itself to a light beam. Such perceptive cells are also possessed by the earthworm, and by the crayfish. In this discussion we shall disregard the possible occurrence in the forms studied of light-sensitive cells other than those in eyes, and shall speak only of visual cells that are grouped into eye structures.

The types of eyes to be considered are:
a. Ocelli, or similar structures, of invertebrates. Beneath a simple polished lens is a vitreous body and retina, along with nerve fibers, pigmented hypodermis cells and accessory cells. A reflecting tapetum may or may not back up the ocellus. When present it supposedly assists in nocturnal vision or at least in light perception.

Both ocelli and compound eyes are present usually, but the ocelli may be

totally absent, as in beetles; compound eyes may be lacking, as in spiders, millipedes, centipedes, Collembola; or both sorts of eyes may be practically absent, as in some ants and termites except winged reproductive individuals. There are many variations of each type of eye.

b. Compound eyes, of invertebrates. Beneath each of the many facets in arthropod eyes is an ommatidium, consisting besides the cornea of lens, rhabdome and retinula, pigment, both distal (iris) and proximal (retinal), sometimes accessory (tapetal) pigment cells, a basement membrane, and fibers of the optic nerve. In bright light the pigment cells elongate around the ommatidium and absorb the excess of light. In dim light they shorten, absorbing a minimum amount of light, and permitting a maximum amount of it to reach the rhabdomes. On account of the withdrawal of pigment the image formed by night-eyes is probably superimposed to some extent, being reinforced by adjacent ommatidia; that of day-eyes is mosaic. Some eyes are fixed as day-eyes, with much pigment; some as night-eyes, with little pigment; some are capable of the adjustment described.

Welsh ('30a, b) describes a very definite migration of distal pigment in eyes of certain shrimps. In another study ('32) he writes that the tapetal or reflecting pigment of crustacean eyes consists of amorphous guanin which forms a layer behind the image receptors, thus increasing eye efficiency at low light intensity. This remarkably effective reflecting pigment moves under the influence of light and dark and is especially motile in certain tropical fresh-water crustaceans which are mainly nocturnal. The nature of the movement of guanin particles seems to approximate the movement of melanin in melanophores, with an additional movement amoeboid in character. In two Cuban species the

distal pigment cells of the eye show a daily rhythmical movement even under constant illumination. He believes the movement to be controlled directly by the blood, indirectly by the nervous system. The reflecting and reticular pigment fails to show this rhythm, thus indicating that the two sets of pigment are independently controlled. Ordinarily the proximal reticular pigment streams distally in the light, proximally in darkness. Bennitt ('32) also observed rhythmical activity of the proximal pigment cells of the crayfish, in the absence of the usual stimuli promoting such changes. He ascribes this rhythm to a metabolic periodicity acting through the circulation, and roughly correlated with the periods of light and darkness to which the animal is subjected in nature. In another paper he and Merrick ('32) present evidence that distal migration, of proximal pigment, while influenced primarily by light, may be induced by agents such as low temperature and carbon dioxide, which reduce the metabolic rate of the animal.

Sharp ('18) describes the divided compound eyes of mayflies as having two parts; one of which is a day-eye, and the other a night-eye, with the two parts widely separated so that the insect appears to have two pairs of compound eyes. The portion of the eye that functions as a day-eye is composed of much smaller facets and the pigment mechanism is that characteristic of day-eyes. The part of the eye that functions at night is composed of larger facets and is fitted to produce a superimposed image.

Hanstrom ('27) believes that in insect eyes the shorter retinal cells may be compared with the rods, the longer ones with the cones of vertebrates.

c. Vertebrate eyes. The well-known vertebrate eye needs no description. There are various devices for adapting such eyes

to the amount of light received, either temporarily or habitually.

The phenomenon of pigment migration in cells of the epithelial layer of the retina occurs quite commonly. As Laurens and Detwiler ('21) explain in the case of the alligator eye, in twilight vision, when the rods alone are capable of being stimulated to any degree, or in complete darkness, the pigment moves back and leaves the spaces between the rods free. Owing to refraction and diffusion, the effect of dim light is greater than if the rods are covered by pigment, when the light can only pass along the axis of the rod. The cones in twilight vision are not functional, on account of their high threshold. They elongate and move out of the way. The rods contract, coming into their best position.

In bright light, the pigment migrates and protects the rods, which have a low threshold, and are made particularly sensitive by the accumulation of visual purple in the dark. The rods elongate, the less sensitive cones are drawn out of the pigment by contraction of the myoids, and are thereby made accessible to stronger light stimulus.

Walls ('28) writes:

If the photomechanical changes in the retina be considered from a comparative standpoint, their story is one of degeneration. In the fishes the phenomena are rapid and pronounced; in the amphibians they are less rapid and in general less marked, though still obviously of functional value; in the reptiles only long exposures have resulted in measurable differences in pigment and cone positions in light and darkness. In the mammals, the phenomena seem to have practically disappeared.

Nocturnal animals generally show a preponderance of retinal rods, while diurnal species often possess more cones than rods. Rods, the mechanism of vision in dim light (of brightness, not of color) are the only visual cells found in the eyes of some noc-

turnal geckoes and bats. Cones, which function in both brightness vision and color reception, are apparently the only visual cells in the eyes of some diurnal lizards. Most turtles and many snakes probably have only cones. Other forms such as crocodiles and their relatives and some snakes possess both rods and cones. Walls ('32b) after finding visual purple in the eyes of many snakes, states that "rods are to be expected, either to the exclusion of cones or in combination with them, in all Boidae, in all Viperidae, and in such Colubridae as have vertical pupils." According to Slonaker ('18) there is a preponderance of color-perceiving cones in the sparrow (diurnal) retina. Woollard ('27) distinguishes between nocturnal and diurnal primates on the basis of retinal structure, the diurnal species having a dominance of cones over rods, especially in the fovea. Cones are normally absent in the mouse (Keeler, '28; Moody, '29). Verrier ('32) reports retinas that seem to contradict this Duplicity Theory. The classic definitions of rods and cones are subject to some revision. It is possible that a re-examination of the visual cells in the retinas which she reports to be exceptions may bring them into harmony.

There are other kinds of adaptation. Movements of the iris regulate the amount of light reaching the retina. Reduction of pupil size protects the retina from strong light. Dilation makes all possible illumination available in dim light. In many amphibia the iris is capable of moderate contraction or expansion. Extensive movement may occur in many reptiles, and a vertically elliptical pupil characterizes the eyes of numerous nocturnal species. Walls ('32a) explains that "a vertically elliptical pupil is capable of more complete closure than is a round pupil. . . . The pure-cone reptilian eye not being subject to dazzle at ordinary

intensities is served quite well by a round pupil, while a rod-and-cone eye such as that of the rattlesnake must have an elliptical pupil. The pure-rod eye sometimes has a pupil which is capable of absolute closure, as in many geckoes." He also notes that all mammals which have vertical pupils are nocturnal, although most nocturnal mammals have round pupils. Kolmer ('26) reports for bats an especially developed sphincter muscle in the iris. Most nocturnal birds have large eyes with pupils capable of exceptional dilation. Walls ('28) considers the forward evolution of the iris reaction, culminating in the very rapid and extensive response found in the mammals, to be correlated with the backward orthogenesis of photomechanical changes, as noted above. He observes "Certainly the rapid pupil reaction, measured in seconds, is a decided improvement over the sluggish pigment and cell movements whose minimum reaction time at best, in certain fishes, is many minutes."

Walls ('31) also indicates that we may expect to find colorless lenses in the eyes of nocturnal snakes, for reasons opposite to those that have brought about yellowness of lens (promoting visual acuity) in several diurnal species investigated by him. He writes that "Snakes with vertical pupils and nocturnal habits would have no need of yellow lenses, in fact such would be absolutely detrimental to a nocturnal snake since they would decrease the already low intensity of the available illumination." This principle holds true in other animal groups. Walls and Judd ('33) observe that typical nocturnal vertebrates also have clear corneae and colorless droplets in the retinal cones. (Rods possess no droplets.) Usually there are neither colored maculae nor plexuses. That is, nocturnal vertebrates usually lack the yellow and red intraocular filters

found in one or another of these forms in most sun-loving species.

In nocturnal mammals Kahmann ('30) observes that the eye and lens are relatively large, the lens strongly curved and highly refractive. He reports that in Ungulates, Carnivores and Primates the ciliary muscle is well developed and accommodation is better than in other forms examined, but he believes that in general there is little accommodation in the eyes of nocturnal lower mammals, due to the size and hardness of the lens.

The presence of a tapetum is an almost absolute criterion of a nocturnal animal. This structure behind the retina reflects back the light entering the eye, causing the well-known shining of eyes in the dark. This may be observed in the eyes of cats, opossums, kinkajous, alligators, etc. It is believed that reflection increases the effect of a faint light, by causing it to pass through the retina a second time. In structure the tapetum varies among different groups. In alligators it consists of whitish guanin granules included in cells of the pigment epithelium. The "*tapetum lucidum*," choroidal reflecting structure in the eyes of carnivores, ruminants and perissodactyls, consists of fibrous tissue. The colors of glow observed in tapetal reflections are probably due to surface colors and interference phenomena.

SUMMARY

1. Absence of light is the most characteristic factor of the nocturnal environment, for vertebrates at least. Many animals appear to be attuned to a certain range of intensity of light. The degree of activity of nocturnal animals may be modified by this and other factors, such as temperature, humidity and rate of evaporation. Nocturnal rhythms, once established, may be exhibited even when the animals are kept

under constant conditions of illumination, humidity and temperature.

2. Possible advantages of the nocturnal habit include the avoiding of daytime enemies, easier obtaining of preferred food, avoidance of excessive evaporation from the body, and easier communication between individuals. For any one species, the reasons applicable can only be conjectured.

3. The adaptations to nocturnal life are chiefly the unusual refinements of one or more of the senses. These are differences of degree rather than of kind and are difficult to analyze, especially since the senses are not employed singly so often as collectively. With the possible exceptions of luminescence and some adaptations of vision, there is observed no modification that might not be fully as useful by day as by night.

4. The closely related senses of smell and taste (and general chemical sense) are relatively the most important for nocturnal use. The sense of smell, frequently aided by organs of scent production, assists in the congregating of individuals, in following trails, in sex attraction, in locating food, and in the detection of enemies and friends. The sense of taste has special usefulness at night for inspecting food which cannot be seen.

5. The sense of touch is of value at night in moving about, in inspecting food or other objects encountered, and in perceiving vibrations, this last faculty passing into that of hearing.

6. The thermal sense plays a part in

regulating the time and intensity of activity, especially among insects.

7. The sense of hearing, often correlated with sound production, is important in the detection of approaching enemies or victims, and for communication. Sound-making on the part of animals serves to frighten away enemies, to warn others of their approach, to attract and woo mates, to communicate general information.

8. Eyes present more definite anatomical adaptations for nocturnal life than any other sense organs. Light production probably has some part in sex attraction and congregating, and may serve as a warning signal.

9. The adaptations for nocturnal vision found among invertebrates include the division of the eye into two parts, each with characteristic structure and one of which is for nocturnal vision; pigment migration; and the presence of a reflecting tapetum.

10. Keeness of vision at night among the vertebrates depends anatomically on the possession of a rod-rich retina, on pigment withdrawal and rod shortening, and often on the presence of a light-reflecting tapetum, by means of which the rods are doubly stimulated. These processes may be accompanied or (especially in mammals) even largely replaced by accumulation of visual purple and related substances, and by iris dilation. Frequently the iris has a vertical aperture. Typical nocturnal vertebrates lack the yellow or red intraocular filters characteristic of nocturnal forms. They also tend to have relatively large eyes. Other possibly useful adaptations are mentioned.

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HYPERPARASITISM IN PROTOZOA

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THE PARASITES OF PROTOZOA

THE interrelations among organisms in nature are wonderfully diverse. Symbiosis—the association of organisms for their mutual advantage; and parasitism—the existence of one organism at the expense of another—are two opposite extremes of the same phenomenon.

Parasitism has attracted much attention. Among plants and animals parasites are very numerous. Only two phyla of animals, Echinodermata and Tunicata, contain no parasitic forms. Some classes of animals, such as the Sporozoa, Trematoda, Cestoda, and Acanthocephala, are exclusively parasitic. On the other hand, all animals and plants may serve as hosts for these parasites. The parasites themselves form no exception in this respect, and may be invaded by other parasitic forms. This phenomenon is known as hyperparasitism. The hyperparasites in their turn are not free from invasion by other parasites. Instances of triple and quadruple parasitism are known.

Parasites of Protozoa have been recognized for many years. Judging from their illustrations Müller (1856), Carter (1856–1857), Wallich (1863), Greef (1866), and other authors have presented descriptions of parasites in Rhizopoda, Mastigophora and Infusoria. Parasitic Protozoa may be parasitized by bacteria, fungi, worms, and other species of Protozoa. The parasite passes into a protozoon through its mouth opening, like any food particle, a food vacuole being formed round it. As shown

by recent investigations, the reaction of a food vacuole is at first either acid or alkaline. The rôle of the acid in the food vacuole is not fully understood. It is supposed that the ingested organisms are killed by it.

Not all of the ingested organisms are killed during the acid phase; some are able to survive unharmed, even finding this environment favorable for multiplication and development. Such a condition is seen among amoebae, when the bacteria they ingest become pathogenic for them. Nägler (1910) has described the invasion of an amoeba (*Amoeba limax* in type) by cocci. I have had an opportunity of observing the same amoeba, in plate-culture, invaded also by cocci. The latter multiplied within the cytoplasm of the amoebae, formed large clumps, and at last brought about the death of their hosts.

BACTERIAL PARASITES

The bacterial infection of free-living Protozoa has been studied rather fully by Petschenko in the case of *Paramoecium caudatum*. This author revealed the occurrence of bacteria (*Drepanospira mülleri*) not only in the cytoplasm, but in the nucleus as well. In both cases the bacteria multiplied profusely, occupied a considerable volume in the body of the ciliate, and finally caused the death of the host.

The portal by which bacteria gain entrance to the body of the host may be not only the mouth opening, but the whole body surface of a protozoon. *Opalina ranarum*, a ciliate parasitic in the intestine

of certain Amphibia, lacks a mouth opening, the food material passing into the body through the surrounding pellicle by osmosis. When studying the cytoplasmic inclusions in *Opalina* (1922-1923), I had the opportunity of observing in the cytoplasm of some individuals a large number of bacteria gathered in clusters. It seemed probable that the bacteria penetrated the damaged pellicle, but it is also possible that bacteria might pass through the intact membrane, when under the influence of certain external factors chemical changes take place in it.

PARASITISM DUE TO FUNGI

Protozoa are most frequently attacked by Chytridia, fungi which have been known for many years to occur in them. The first observations were made on free-living protozoa. Dangeard (1895) found these fungi within the nucleus of *Amoeba verrucosa*, and named them *Nucleophaga amoebae*. During development and formation of zoconidia the nucleus of the amoeba degenerated and the amoeba itself succumbed. Gruber (1904) noted similar parasites in *Amoeba viridis*; Penard (1905) in *Amoeba terricola*, Doflein (1907) in *Amoeba vespertilio*, Mercier (1907-1910) in *Endamoeba blattae*.

In parasitic Protozoa, Chytridia attack either the cytoplasm or the nucleus. At the present time these fungi are known in parasitic Amoebae, Mastigophora and Ciliata.

Leger and Duboscq (1904) found the cytoplasmic parasite *Sphaerita* in *Endamoeba salpae*, parasitic in the rectum of the marine fish, *Box salpa* and *B. boops*. Wenyon (1907) observed similar parasites in *Endamoeba muris* from the intestines of mice. Mackinnon (1913-1914) describes cocci-shaped parasites in *Endamoeba minchini* from the intestine of *Tipula* (sp.) larvae. I observed (Sassuchin, 1929) cytoplasmic parasites in *Mastigina hylae* from the intestines of tadpoles of *Rana*.

Cytoplasmic parasites are known also in the intestinal amoebae of man, such as *Endamoeba coli* (Cragg, 1919; Nöller, 1921; Epstein, 1922; Lwow, 1925), *Endamoeba histolytica* (Nöller, 1921; Lwow, 1925), *Endolimax nana* (Dobell, 1919), *Iodamoeba bütschlii* and *Dientamoeba fragilis* (Nöller, 1921).

As a rule these parasites occur as rounded bodies within the cytoplasm of the amoebae. Such bodies, measuring 1 to 2.5 microns in diameter, are scattered in the protoplasm either singly or more frequently united into groups sometimes closely resembling sporangia, except for the absence of a membrane. Such groups may occupy three fourths of the protoplasm of the host; moreover, there are not infrequently several groups in one amoeba. As a direct consequence of such invasion the parasitized amoebae die. By the rupture of their bodies the parasites escape into the lumen of the intestinal canal and here they may invade other amoebae. Parasites were found by us in the intestinal amoebae of monkeys (*Macacus rhesus*) (Sassuchin, Popow, Kudrjawzew and Bogenko, 1930). In the protoplasm of *Endamoeba pisheci*, rounded clumps of bodies enclosed in a vacuole were revealed. In their form, structure, and position they were identical with the parasites that occur in the intestinal amoebae of man. Occupying a considerable part of the body of the amoeba (see fig. 1) they destroyed its protoplasm and the amoeba succumbed. It is to be noted that in the intestinal amoebae of monkeys the parasites are of rare occurrence. Quite a different picture was observed in the intestinal amoebae of a steppe suslik (*Citellus pygmaeus* Pallas). Parasites occurred in large numbers in *Endamoeba citelli*. In certain microscopic fields all the amoebae were invaded by these fungi (fig. 2). Within the cytoplasm of their host, the parasites are collected in groups of separate

bodies, each group looking something like a sporangium. These bodies are never to be seen enclosed in one membrane, but one

amoeba, but sometimes much larger. Each body is oval or round, its size being from 1 to 2 μ in diameter (fig. 4). The parasites

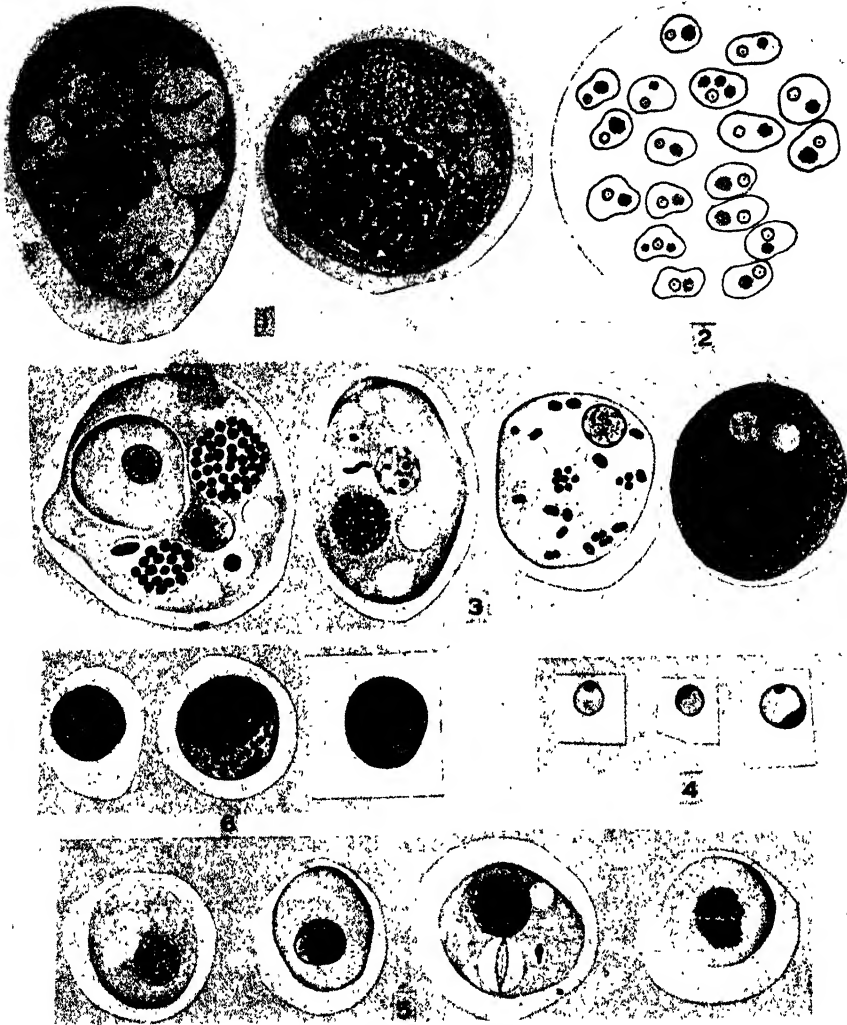


FIG. 1. CYTOPLASMIC PARASITES SPHAERITA IN ENDAMOEBA PITHECI

FIG. 2. GROUP OF ENDAMOEBA CITELLI IN A MICROSCOPIC FIELD. CYTOPLASM OF AMOEBAE INVADDED BY SPHAERITA

FIG. 3. ENDAMOEBA CITELLI WITH SPHAERITA IN ITS CYTOPLASM

FIG. 4. SEPARATE PARASITES OF SPHAERITA IN ENDAMOEBA CITELLI

FIGS. 5 AND 6. NUCLEOPHAGA IN NUCLEUS OF ENDAMOEBA CITELLI

or several groups of such bodies are present in the cytoplasm of an amoeba. These groups vary considerably in size, at times being quite as large as the nucleus of the

were studied in films fixed with Schaudinn's or Flemming's fluid and stained with Heidenhain's iron-haematoxylin. In stained preparations each individual body

is seen to possess a clear interior and a conspicuous membrane staining deeply with haematoxylin. Each of these bodies has on one side or on both, crescent-shaped thickenings intensely stained with iron-haematoxylin. In some parasites large vacuoles are present, situated at one end of the organism. In certain individuals one sees near the membrane a deeply staining granule which is probably the nucleus of the parasite (fig. 4).

Sometimes the parasites are arranged singly in the protoplasm of the amoeba, each being from 2 to 2.5μ in diameter, but identical in structure with those united into groups. Since the parasites occupy a considerable volume of the cytoplasm, it is probable that they impede normal metabolism in the host. Enlarging in size they at last destroy the body of the amoeba. The large numbers of these parasites present in *Endamoeba citelli* suggest the possibility that this amoeba is being gradually exterminated as a result of this parasitism. It is to be noted that the same cytoplasmic parasites are of common occurrence in amoebae of the American ground-squirrel (*Citellus tridecemlineatus*) and are present in large numbers (Becker, 1926).

It would be of interest to carry out experiments on the influence of these parasites upon the development of amoebae in the intestinal canal of the host. It might be possible to use these hyperparasites of amoebae to control the pathogenic protozoa of man's intestine (Lwow, 1925).

So far as their systematic position is concerned, the question is still uncertain. Most workers believe these parasites to be Chytridia and place them in the genus *Sphaerita*. I found (Sassuchin, 1931) in the same amoeba (*E. citelli* from the suslik) parasites which attacked the protoplasm as well as the nucleus of the host (figs. 5 and 6). At the initial stages of infection one may observe at the periphery of the

nucleus one or several parasites, measuring from 1 to 2 microns in diameter. In fixed and stained preparations they show very little internal structure, but in some individuals one can easily distinguish a deeply staining granule, which is probably the nucleus of the parasite. The parasites multiply within the nucleus of the amoeba and completely fill it. The nucleus undergoes hypertrophy, enlarging sometimes to twice the normal size. As a direct consequence of nuclear hypertrophy the whole protoplasm increases in quantity and the nuclear membrane becomes invisible, which is undoubtedly the last stage in the life of the amoeba.

The morphological peculiarities of the parasite, and the effect it exerts upon its host permit us to place it in the genus *Nucleophaga*.

The hyperparasites of pathogenic Mastigophora were first seen by Wenyon (1907) in *Trichomonas*. Cunha and Muniz (1923) observed the parasites also in *Trichomonas*. W. Yakimoff (1929) found hyperparasites (*Micrococcus batrachorum*) in the cytoplasm of *Trichomonas batrachorum*.

We have observed (Sassuchin, Popow, Kudrjawzew, and Bogenko, 1930) more than once parasites in the protoplasm of *Trichomonas muris* from the intestine of *Mus musculus*. In their morphological characters, structure and position in the host, they closely resemble the hyperparasites of amoebae belonging to the genus *Sphaerita* (fig. 7). In certain instances the parasites were irregularly scattered through the protoplasm of *Trichomonas*, but the dimensions, shape and structure of each parasite were similar to those described above (fig. 5). We could not definitely identify the parasites of amoebae with those of flagellates, but it seems very probable that they are closely related.

We have also observed parasites re-

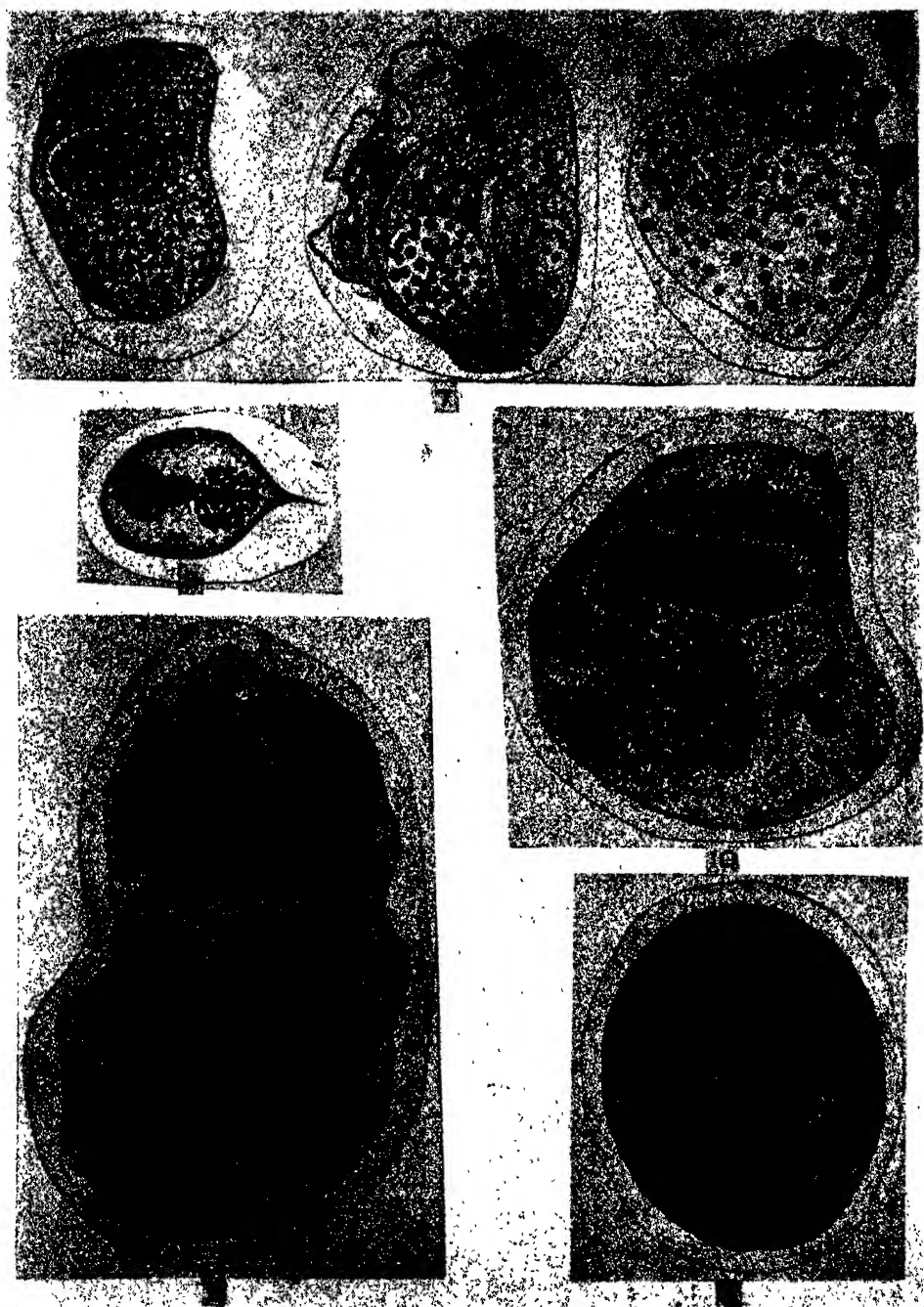


FIG. 7. CYTOPLASMIC PARASITES IN *TRICHOMONAS MURIS*

FIG. 8. CYTOPLASMIC PARASITES IN *CHILOMASTIX MAGNA*

FIGS. 9 AND 10. CYTOPLASMIC PARASITES IN *NYCTOTHERUS OVALIS* (SECTION)

FIG. 11. "SPORANGIUM" FROM CYTOPLASM OF *NYCTOTHERUS OVALIS*, DRAWN SEPARATELY

sembling those of *Trichomonas* in *Chilomastix magna* Becker, 1926. In this case, however, we have not had sufficient material to study and describe them in detail (fig. 8).

In 1925 I had an opportunity of observing two kinds of hyperparasites in the cytoplasm of a ciliate, *Nyctotherus ovalis*, from the intestine of *Periplaneta orientalis* (Sas-suchin, 1928). Some were quite similar to those described above, the others were coccoid organisms. Not infrequently both kinds of parasites occurred simultaneously in the host, though sometimes they were seen separately. To the first kind belonged spherical structures, resembling sporangia, about 30 microns in diameter, surrounded by a thick membrane. These sporangia contained masses of spores (figs. 9, 10 and 11). Such sporangia occurred either singly or collected into small groups. Sometimes as many as nine were seen in the body of a ciliate. The other structures, which were found in *Nyctotherus ovalis*, were only the developmental stages of the same parasite. At the initial stages of infection one may observe separate spores of the parasite in the protoplasm of the ciliate. When stained with iron-haematoxylin or alizarin-toluidin-blue, a single spore appears, ovoidal or ellipsoidal in shape, 1.5μ broad and 2μ long, with a distinct membrane, and staining pinkish-yellow with alizarin. In properly differentiated preparations the spore membrane appears to be uniformly thick throughout, but the cytoplasm is compressed by a large vacuole and consequently the contents of the spore seem to be essentially thickened towards one end. The presence of a nucleus in these spores is still questionable. Such spores may be observed in fully formed sporangia, lying within the membrane and outside the sporangium either in the lumen of the intestine or, as was demonstrated, in the cytoplasm of the ciliate.

The subsequent stages of the parasite are represented in my preparations by sporangia in early stages of development. Such a sporangium is a cytoplasmic body containing numerous small nuclei. The size of a sporangium varies from 10 to 25 microns in diameter. It is always enclosed by a membrane, which is thicker in larger and correspondingly thinner in smaller sporangia. In form, the sporangia are usually spherical or ellipsoidal. In my preparations there are, it appears, younger stages of development, similar to those described by Chatton and Brodsky in *Sphaerita* parasitic in *Amoeba limax*. In these stages the parasite appears to be an amoeboid body with one or two nuclei of the karyosome type. Nuclear division then takes place, so that a multinucleate amoeboid sporangium is formed. While this multinucleate amoeboid body increases in size, the gradual thickening of its membrane is taking place, its maximum thickness being attained in the mature sporangium. The cytoplasm enclosed within the membrane segments into numbers of spores. A similar process has been described by Dangeard in *Sphaerita endogena*, and several authors have seen it in other Chytridia.

The size of a mature sporangium, which depends on the size of the amoeboid body, ranges from 20 to 30μ . The vast majority of individuals are spherical, more rarely ovoidal and exceptionally irregular in shape. The membrane of a fully grown sporangium attains a thickness of 1 micron. The further fate of such a sporangium may vary. In certain cases its membrane ruptures within the body of the ciliate; in others the sporangium escapes into the lumen of the intestine after the death of the ciliate. I have observed several times the emergence of spores from the sporangium within the body of the host. In preparations stained with iron-haematoxylin this stage appears as follows: by rupture of the membrane

at one end, the spores are set free in the cytoplasm, and are then dispersed by cytoplasmic streaming through the whole body of the ciliate. Some spores remain within the sporangium whose wall visibly fades away. Such a half-empty sporangium, or rather its membrane, may remain intact in the cytoplasm of the host. I have observed many of the stages described during life in a moist chamber, wherein the ciliates lived as long as 12 days in a drop-let of intestinal contents diluted with physiological salt solution or with Ringer-Lock's fluid.

The harmful effect of the parasite upon the ciliate host was noticed only when, by increasing in size, it filled a large area in the ciliate. When located at the posterior end of the ciliate, the parasite may occupy one third of its body and at last causes the death of its host. First of all the sporangia exert a mechanical pressure upon the cytoplasm, and sometimes upon the macronucleus of the host. Then the invaded ciliates exhibit striking changes in their physiological processes. The contractile vacuoles pulsate sluggishly as compared with those of normal individuals. The contraction is correspondingly slower in those ciliates in which the larger amounts of cytoplasm, especially at the posterior end, are occupied by the parasites. The parasites prevent the normal circulation of food-vacuoles in the cytoplasm of the host. It is highly probable that all this taken together influences the formation of food-reserve materials by the ciliate. The change in number of glycoproteid granules is especially noticeable. These often occur in abundance dispersed through the whole cytoplasm in the form of oval granules that appear to be somewhat flattened on one side. During the growth of the parasite the number of these granules decreases gradually, until at last they disappear. At later stages changes take place

in the macronucleus. The coarse round lumps disintegrate into a number of small granules. In the last moments of life these granules are in violent movement; then they become fewer and fewer, and the macronucleus finally seems to become empty. The lashing motions of the cilia become more and more sluggish, and the ciliates cease to progress. The movement of cilia gradually terminates, and at the same time the contractile vacuole ceases to pulsate. After this the cytoplasm disintegrates rapidly and the spores are set free. It is to be noted that when the sporangium ruptures within the cytoplasm of the host, the latter succumbs almost immediately.

In certain cases parasites occur in the cysts of this protozoon.

In some individuals of *Nyctotherus ovalis* taken from the same material I found in the cytoplasm many granules which I mistook at first for cytoplasmic inclusions. These are extremely small bodies, round in shape and about 0.3μ in diameter (figs. 9 and 10). They do not occur singly but are arranged in groups of different shapes and sizes. Such groups are irregularly scattered through the body of a moving ciliate, or its cyst; and may occupy the greater part of the host. When stained, the separate bodies are distinctly visible, but show very little internal structure. In living organisms the groups are fairly distinct because of their refringence. *Intra vitam*, they stain feebly with Janus green and brilliant cresyl blue, and do not stain at all with neutral red.

It is of interest to mention the arrangement of these inclusions in the cytoplasm of a ciliate in which the parasite *Sphaerista* occurs. In figure 8 one sees a sporangium whose surface is completely covered with these bodies as though surrounded by a capsule. It is to be noted that in the earliest stages of development of the parasite both the inclusions and the parasite

itself lie freely in the cytoplasm without any connection with one another. But with the growth of *Sphaerita*, when it begins to occupy a large proportion of the cytoplasm of its host, these bodies gather near the surface of the sporangium.

At the first moment of observation I was doubtful about the nature of these inclusions. To determine whether they were cytoplasmic granules of the chondriosome type, volutin granules or glycoproteid bodies, specific methods of staining and several microchemical analyses were carried out. The chondriosomes in *Nyctotherus ovalis* are small, rod-shaped bodies, more or less uniformly distributed throughout the cytoplasm (Sassuchin, Ostroumow). The mentioned bodies did not show typical glycogenic staining with Best's carmine method, nor did they give a characteristic glycoproteid reaction with Fischer's safranin-tannin stain. They were insoluble in ptyalin and did not show the staining characteristic of glycogen and of glycoproteid bodies as a result of treatment with iodine solution. Mayer's method to demonstrate volutin granules (methylene blue + H_2SO_4) and the reaction with $\text{I} + \text{H}_2\text{SO}_4$ also did not give a characteristic staining reaction. Their resistance to fat solvents (equal portions of ether, acetic acid and 100 per cent alcohol) and a negative reaction with Sudan III after fixation with 10 per cent formalin, revealed that they were neither chondriosomes nor fat bodies.

Having observed clumps of these inclusions in living ciliates confined in the moist chamber, I noticed that they were increasing both in size and in number. This suggested the idea that a multiplicative process takes place among them. The inconstant presence of these bodies in ciliates, the absence of a food vacuole enclosing them, their increase in size,

their situation in the cytoplasm, when another parasite (*Sphaerita*) occurs, as well as their presence in the encysted form, all this taken together induces me to believe that these bodies are neither food particles, nor foreign particles ingested by the ciliates. They appear to be living organisms, probably bacteria, which may multiply within their host's body. The presence of these bodies in certain individuals only affords evidence for the belief that we here see the phenomenon of parasitism rather than that of symbiosis.

PROTOZOAN PARASITES

Besides bacteria and fungi, Protozoa themselves may parasitize other Protozoa. Doflein discovered *Mastigamoeba* in the cytoplasm of a free-living ciliate, *Stentor*. The developmental stages of certain Suctorians (*Sphaerophrya*) take place in the cytoplasm of *Paramoecium*. These parasites are also known within parasitic ciliates. Lutz and Splendore (1908) described a microsporidian, *Nosema balantidii*, in *Balantidium* sp., parasitic in the cloaca of *Bufo marinus*.

Parasitic Microsporidia are known in gregarines. Leger and Duboscq (1909) found a microsporidian in the cytoplasm of *Frenzelina conformis*, a gregarine parasitic in the intestine of a crab, *Pachygrapsus marmoratus*. This microsporidian is found in different developmental stages of the gregarine, including its encysted forms. The crab's tissues are free from infection. The microsporidian is easily recognized in fixed and stained preparations. Under low magnification the microsporidia appear in small granules scattered throughout the cytoplasm of the gregarine. The structure of the spores is similar to that of *Nosema bombycis*, the average length being 2.8 microns.

Another microsporidian, *Perezia lankesteriae*, attacks the cytoplasm of *Lankesteria ascidiae*, a gregarine parasitic in the intestine of *Ciona intestinalis*. This microsporidian, as well as *Nosema frenzeliniae*, never invades the host's tissues but occurs only in the cytoplasm of the gregarine.

A microsporidian, *Nosema marinus*, is a form of still more interest. It occurs in the cytoplasm of a myxosporidian parasitic in fish, *Coris julis* and *Coris giofredi*.

Parasites are also known in the bodies of gregarines from the intestine of Polychaetae for which Caullery and Mesnil (1919) created the separate family Metchnikovellidae. As a typical form of this family the authors have described *Metchnikovella spionis*, parasitic in a gregarine, *Polyrhabdina*, from the intestine of *Spio martinensis*.

The systematic position of these parasites of gregarines is uncertain. Some observers consider them to be allied to the Microsporidia; others believe them to be closely related to the Ascomycetes (Caullery and Mesnil) or to the Haplosporidia (Averintzev).

A METAZOAN PARASITE

Lastly, of particular interest is in my opinion the finding in a protozoan host of a metazoan parasite. Schubotz has found a nematode in the cytoplasm of a ciliate, *Pycnothrix monocystoides*, from the intestine of *Hydrax capensis*.

CONCLUSION

In studying the life-cycle and cytology of Protozoa, we should not forget that parasites may be present. They often confuse the laboratory worker, and are sometimes a cause of grave mistakes. It is sufficient to recall that Walker mistook parasites of *Nyctotherus ovalis* (described above) for one of the developmental stages of this ciliate; while Goldschmidt interpreted the cytoplasmic parasites of *Mastigina* as extranuclear chromatin.

Parasites are enemies of mankind, but the parasites of parasites are our friends. It is probable that in certain cases they help the infected host to conquer his infection. We should, therefore, not neglect these hyperparasites but study them more thoroughly, since they deserve careful investigation.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of THE QUARTERLY REVIEW OF BIOLOGY, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

BRIEF NOTICES

EVOLUTION

FUNCTIONAL AFFINITIES OF MAN, MONKEYS, AND APES. *A Study of the Bearings of Physiology and Behaviour on the Taxonomy and Phylogeny of Lemurs, Monkeys, Apes, and Man.*

By S. Zuckerman. Harcourt, Brace and Co., New York. \$3.00. 8½ x 5½; xviii + 203; 1933.

This book is an appropriate sequel to the author's recent *The Social Life of Monkeys and Apes* in which are continued his studies of the broader aspects of the inter-relationships of the primates. A not unsuccessful attempt is made to allocate the phylogenetic position of the primates on the basis of such functional and physiological characteristics as the mechanisms of reproduction, blood reactions, receptor organs, behavior patterns, diseases and parasites, hybridization, and cortical physiology. On the whole the phylogenetic implications of this original method of classification are in agreement with the more orthodox taxonomy based upon morphology. The book is well written, contains an extensive and very valuable bibliography, and an index.



Fossil Floras of Yellowstone National Park and Southeastern Oregon. *Contributions to Palaeontology.* Carnegie Institution of Washington Publication No. 416. Containing following monographs: *Fossil Floras of Yellowstone National Park. Part I.*

Coniferous Woods of Lamar River Flora, by Charles B. Read; *The Trout Creek Flora of Southeastern Oregon*, by Harry D. MacGinitie.

Carnegie Institution of Washington, D. C. \$1.50 (paper); \$2.50 (cloth). 10 x 6¼; 68 + 16 plates; 1933.

There are two monographs in this volume, one on fossil trees and the second on fossils of the small flora. The last adequate account of the plant fossils from the Yellowstone area, by Knowlton, was published in 1899, so that it seems to be time to bring matters up to date. There are six plates of microscopic sections from the fossil trees and 16 plates of seeds and leaf prints, all extremely good.

Dr. Read concludes that the genus *Pinus* was established by Upper Eocene or Lower Oligocene times. Dr. MacGinitie emphasizes the resemblance between the Miocene forest of the Trout Creek region of Oregon and the living floral association of northeastern Asia (Japan and Manchuria).



THE EVOLUTION OF MORALITY.

By George Whitehead. John Bale, Sons and Danielsson, London. 10s. 6d. net.

8½ x 5½; iii + 340; 1933.

The thesis of this book is that morality has never rested on religious sanctions and that it has its roots in animal behavior. Unfortunately, Mr. Whitehead has just two means of studying animal

behavior: one to imagine what animals would do if only they were Englishmen crawling on all fours, the other to pile up quotations from books written by other bookish men. Neither of these methods seems to have led him to any new conclusions. He rises to heights of eloquence only when he denounces women, war, and religion. At other times he is pretty tiresome.



THE GENERAL THEORY OF EVOLUTION.

By Malcolm MacTaggart. W. Heffer and Sons, Cambridge. 1s. 6d. net. 7½ x 5; vi + 50; 1933 (paper).

Starting with little and figuratively adding nothing the author amuses himself in a metaphysical manner throughout some fifty pages by toying abstractly with profundity and foolishness, by laughing once at the absurdity of pretentious moral suasion, and concluding by asking a few questions which he regards as unanswerable. The subtle art of engaging a reader's interest or imagination finds no place in the rattle of words in which the evolutionary events as given by modern science are held to follow the preconceived logical system of Hegel. *Trust* as opposed to *belief* is given as the ideal that will enable human evolution to proceed beyond its present state.



MAN AND THE VERTEBRATES.

By Alfred S. Romer. University of Chicago Press, Chicago. \$3.00. 9 x 6; vii + 427; 1933.

A brief, comprehensive survey of vertebrates and human evolution written for biological students at the University of Chicago under the new plan of college work. The text serves as outside reading for those students attending the author's lectures on the vertebrates and on the human body. The volume is extensively illustrated. Many of the views of fossil remains and reconstructed groups in museums have not hitherto appeared in text books. The volume contains no bibliography but is indexed.

AN INTRODUCTION TO THE STUDY OF FOSSILS (*Plants and Animals*). Revised Edition.

By Hervey W. Shimer. The Macmillan Co., New York. \$4.00. 7½ x 5½; xviii + 496; 1933.

This is the second edition of a textbook intended for college students who begin the study of paleontology without previous work in biology. Accordingly, the description and discussion of living plants and animals goes side by side with the treatment of fossil forms of the same phyla. It is well illustrated and has an excellent index.



GENETICS

NATURE AND NURTURE.

By Lancelot Hogben. W. W. Norton and Co., New York. \$2.75. 8½ x 5½; 144; 1933.

This book, originally delivered as a series of William Withering Memorial Lectures at the University of Birmingham, covers somewhat the same ground as the author's *Genetic Principles in Medicine and Social Science*, which was noticed in Volume VII, page 477, of this REVIEW. However, it lays more emphasis on statistical methods appropriate to the study of human genetics and less on dubious generalities than did the latter book. The use in genetic analysis of the Principle of Random Mating and of the study of consanguineous parentage and familial diseases is illustrated. The author emphasizes the interdependence of nature and nurture, and concludes that while the correlation technique may show the existence of gene differences whose manifest effect is not affected by differences of environment to which different members of a population are exposed

The belief that a comparison between observed correlation of relatives and correlations based upon purely genetical assumptions provides us with a measure of the influence of nurture is not justified, because of the close relationship between the distribution of gene differences and differences due to environment in populations of viviparous animals which live in families, especially when, as with human populations, the environment of different families may differ greatly.

In so far as a balance sheet of nature and nurture has any intelligible significance, it does not entitle us to set limits to changes which might be brought about by regulating the environment.



VERERBUNGSLEHRE. *Mit besonderer Berücksichtigung der Abstammungslehre und des Menschen. Zweite Auflage. Band II: Sexualität und allgemeine Probleme.*

By Ludwig Plate. Gustav Fischer, Jena. 30 marks (paper); 32 marks (cloth). 9½ x 6½; xiv + 678; 1933.

This is the second volume of a series of three of the second and expanded edition of the author's masterly *Vererbungslehre*. Sexuality and problems relating to it are discussed in this volume, 361 pages being devoted to special discussions and 263 to theoretical problems. The author develops the material in the same thorough manner which characterized the first volume noticed previously in these columns (Vol. VIII, p. 103). A bibliography of 28 pages is appended.



GENERAL BIOLOGY

CHARLES DARWIN'S DIARY OF THE VOYAGE OF H.M.S. "BEAGLE."

Edited from the MS by Nora Barlow. The Macmillan Co., New York. \$6.50. 9½ x 6½; xxx + 451; 1933.

This volume is a documentary contribution of first class importance to the history of biology. Since its first appearance in 1839 Darwin's *Voyage of the Beagle* has been one of the most widely read books on natural history ever published. It is now justly regarded as one of the world's great classics. But hitherto all that we have had is the finished work, as Darwin gave it to the world.

The volume now before us, edited with the most painstaking care and accuracy and a fine sense of the highest type of bibliographic scholarship by one of Darwin's granddaughters, gives the complete text of the original diaries—"eighteen little pocket-books"—in which Darwin made his daily notes and from which he composed the *Journal of . . . the Voyage . . .* for publication. It is a superb production, from every point of view.

It contains such homely details as that at the next opportunity there are to be purchased "night-caps," "2 lbs. common soap," etc. It shows how Darwin's ideas changed about evolutionary problems. It shows how bad a speller a very great man may be. Altogether it is a great book, which no biological library, public or private, can be without.



DYSHARMONIES ET DISCONTINUITÉS DANS LA CROISSANCE. *Actualités Scientifiques et Industrielles 95. Exposés de Biométrie et de Statistique Biologique I.*

By Georges Teissier. Hermann et Cie, Paris. 10 francs. 9½ x 6½; 39; 1934 (paper).

In the first of a series of monographs on mathematical biology Teissier describes the researches on the relative growth of the different parts of an organism which have been made by various workers, notably by Huxley and by Teissier himself. The rate of growth of one organ in a wide variety of forms is found to be either equal or proportional to that of other organs. This law of growth may be derived from the assumption, for which there is experimental evidence, that the rate of growth of an organ is proportional to the mass of the organ and to the amount of food available. In some cases the rate of relative growth changes abruptly at some stage in the development of the organism. This change may perhaps be the result of the coming into action of new hormones, although this hypothesis is not yet definitely confirmed by experimental evidence. Altogether this is an interesting account of a line of work which may shed new light on the complex problem of growth. There is a bibliography of one page.



THE LIVING WORLD. *An Elementary Biology.*

By Helen G. Mank. Benj. H. Sanborn and Co., Boston. \$1.68. 7½ x 5½; xxiv + 673; 1933.

A book is here offered for high school pupils which aims to teach them to ob-

serve accurately. To this end, the text itself does not give the information to answer all the questions but it must be supplemented by observation, other books, and the teacher. Purposely, much more material is given than can be used in a single course; part of this is arranged as additional work for quick pupils. Many useful and interesting teaching devices are included. We would personally take exception to some of the statements made, such as part of the section on alcohol. Throughout the book there is considerable emphasis and space devoted to the public health aspect of biology which is surely laudable. As a whole the book seems somewhat uneven—some parts are very simple and some too advanced for most high school pupils. Although the author states that the book has grown out of an actual course, it seems rather too ambitious in scope and material required for many schools.



THE SCIENCE OF RADIOLOGY.

Edited by Otto Glasser. Charles C. Thomas, Springfield, Ill. \$4.50. 9½ x 6½; xiii + 450; 1933.

Twenty-eight American scientists have contributed to this extremely fine book on radiology. It is part of the program of the radiologists developed in connection with the Century of Progress Exposition and the first International Congress of Radiologists. It is edited by and the first two chapters are written by Otto Glasser. Apparently everything is here—history, physics, apparatus, use. Some of the chapters are highly technical, but they contain just the sort of information one wants. Muller has an excellent chapter reviewing his x-ray induced mutations and Packard has summarized his work on the biologic effects of x-rays. The bibliographies are an especially valuable feature. There are both name and subject indices.



CAVERNS OF VIRGINIA. *Commonwealth of Virginia State Commission on Conservation*

and Development, Virginia Geological Survey, Bulletin 35, Educational Series No. 1.

By William M. McGill. Virginia Geological Survey, Box 1428, University, Va. \$1.00 plus postage. 10½ x 7½; xvi + 187; 1933.

The western portion of Virginia is honey-combed with caverns of an unusual and striking character which attract a large number of visitors throughout the year. This book has been prepared by the Virginia Geological Survey to give to the interested individual a general knowledge of the geological history and physiography of the Appalachian Valley, of methods of cave formation, and of their characteristics. All of the important developed caverns are described in detail. The volume is excellently illustrated with photographs and maps and contains a glossary, a literature list and an index.



SYMBIOSE, PARASITISME ET ÉVOLUTION (*Étude Mathématique*). *Actualités Scientifiques et Industrielles* 96. *Exposés de Biométrie et de Statistique Biologique*. II.

By V. A. Kostitzin. Hermann et Cie, Paris. 15 francs. 9¾ x 6¾; 46; 1934 (paper).

In this interesting study the author develops for the special cases of symbiosis and parasitism various modifications of Lotka's and Volterra's equations for the evolution of a system of species. Applying his equations to Pérez's distribution of number of visceral sacs of *Chlorogaster* in parasitized *Pagurus* he concludes that this is not a case of multiple parasitism but of the budding of a single parasite. There is a bibliography of 17 titles.



MÉTHODES PHYSIQUES EN BIOLOGIE ET EN MÉDECINE.

By P. Lecomte du Noüy. J.-B. Baillière et Fils, Paris. 22 francs. 8½ x 5¾; 194; 1933 (paper).

A simple exposition of the physical methods, instruments and measurements more commonly used by the student of biology or medicine. In very brief form

the author treats of thermostats, density, cryoscopy, surface tension, viscosity, hydrogen ion concentration, electrical conductivity, optical methods, and spectrophotometry. A useful laboratory reference work.



PRÉCIS DE MICROSCOPIE. *Technique. Expérimentation. Diagnostic. Cinquième Edition Entièrement Refondue.*

By M. Langeron. Masson et Cie, Paris.

100 francs. 7½ x 5; xx + 1205; 1934.

This is the fifth edition of an introduction to the use of the microscope in the study of parasitology with the emphasis laid on microscopy as an aid to diagnosis. Methods for the study of most of the phyla of the animal kingdom are given and there are also sections devoted to bacteriology and to plant histology. It is illustrated and has an index.



NACHWEIS DER BIOLOGISCH WICHTIGEN KÖRPER DURCH FLUORESZENZ UND FLUORESZENZSPEKTRUM. *Handbuch der biologischen Arbeitsmethoden. Lieferung 420.*

By Charles Dhéré. Urban und Schwarzenberg, Berlin. 11.50 marks. 10 x 7; 210;

1933 (paper).

Since *Lieferung 40* dealt in some detail with the physical equipment used in studies on fluorescence this number is for the most part limited to the applications of this branch of spectroscopy to the study of relatively pure solutions of biochemically important substances. Methods for the investigation of tissues and body fluids are not given.



THE ORIGIN OF LIVING MATTER.

By H. A. Gray and N. M. Bligh. W. Heffer and Son, Cambridge. 1s. 6d. net.

7½ x 4½; iii + 27; 1933 (paper).

According to the authors the energy of momentum resulting from the detachment of the moon from the earth led to the formation of bi-nuclear or "Vital" atoms. This theory, they state, "will

explain and account for all and every phenomenon of vitalism;" just how is not entirely clear to us.



HUMAN BIOLOGY

LA COSTITUZIONE INDIVIDUALE. *Dottrina. Metodo. Tipi Morfologici. Volumes I and II.*

By G. Viola. Licinio Cappelli, Bologna.

L. 100. 10 x 6½; Vol. I, xx + 455;

Vol. II, v + 397; 1933 (paper).

The concept that the somatic structure of the individual is related to the organic structure and so indicates the predisposition of the individual to disease was revived by Benecke and De Giovanni about 50 years ago. This, the soundest interpretation of medical constitution, is now maintained in Europe only by Viola and his students.

In these volumes are collected the majority of his writings since 1902, in which he has developed this concept especially with regard to the anthropometric method of determining the morphologic types. The work consists of three parts. The first deals with the history and theories of constitution, which the author defines as "the science of the correlated anatomical and functional, physical and psychic characters of the individual."

The second part is very important for its discussion of the difference between constitutional type and anomaly and disease. Here is an excellent criticism of the weakness inherent in the genetic concept of J. Bauer and others.

In the third part are collected his articles on anthropometric measurements. He has devised a special apparatus to be used instead of the anthropometer and apparently more satisfactory for laboratory purposes. The measurements taken that he considers have an anatomical and physiological significance are only nine for the trunk and two for the limbs. From the constants calculated on 350 Venetian male adults he has derived a system of gradation that permits a comparable classification of all individuals.

In this schematic review, justice cannot be done to other important articles which contain the results of investigation on

disease associated with bodily types, the correlation of external measurements with roentgenograms of different organs, etc. There is also an excellent review of the writings on the evolutionary significance of bodily habitus.

No student of human constitution can do without consulting this work which illustrates the basic scientific method necessary for future research.



THE SOCIAL COST OF INDUSTRIAL INSURANCE.

By Maurice Taylor. Alfred A. Knopf, New York. \$3.25. 8 x 5 $\frac{3}{8}$; xxxviii + 421; 1933.

This investigation deals with a social problem of importance which has never been sufficiently considered. The so-called industrial insurance is a special form for people with small incomes, which does not require medical examination and is sold at small weekly premiums. These are collected by the agents, whose salesmanship is of the high pressure variety. It becomes thus relatively expensive for both companies and the policyholders. The result, as even a casual observer will have noted, is that after a period the varying economic state of the insured may force him to ask for cash value or to lapse. In either case he has lost by the transaction. The purpose of this study is to measure this loss, which for the period 1928-1932 the author estimates (for lapsed insurance alone) at almost 200 million dollars. The material is derived almost wholly from the records of three large insurance companies, which may explain why on page 153 the chapter heading ends with an interrogation point: "Do the companies gain from lapses?"

The subject matter includes a brief historical note on the origin of this form of insurance policy, followed by a very clear outline of the difference between it and the ordinary policy. The author proceeds to give the extent of its development in this country and geographical distribution of the insured. Especially well done are the chapters on the analysis of the cost, which is compared with that

of the ordinary form, and his proposals in regard to families dependent on public welfare. His general recommendations include a lowering of the cost with greater consequent benefits to the policy holders, the limitation of sales in ratio to the income, etc. Some of these recommendations are useless, we feel, because unless paternalism increases, a change of method will depend wholly on the attitude of the insurance companies and their estimate of possible profit.



IN THE WAKE OF "THE BOUNTY." To *Tabiti and Pitcairn Island.*

By Charles Chauvel. Endeavour Press, Sydney. 6 shillings. 8 $\frac{3}{8}$ x 5 $\frac{3}{8}$; 157; 1933. This book, a by-product of the author's film of the same name, contains a brief narrative of the mutiny of the *Bounty* and the subsequent history of the mutineers and an account of Mr. Chauvel's own experience in making the film. The most interesting part of the book is the description of the Pitcairn Islanders of today, the descendants of the mutineers. About thirty years ago the island was converted to Seventh Day Adventism, with deplorable effects.

Their new religion has brought to them a mass of modern "taboos" as fantastic as any of the tribal inhibitions of the Polynesian savages of yore. Tea is a drug and disallowed in the homes, while to smoke publicly on the island would be an offence. Baking-soda has been condemned, and the missionaries have even tried to prevent the eating of all meat. The pig, which in the past was so prized on Pitcairn, is to-day an unclean animal, and no one is allowed to own one. All literature except religious books and tracts and a panic-stricken sheet called "The Signs of the Times" are censored from the island. Dancing is not allowed, and only religious records and nursery rhymes are encouraged on the gramophone. They have been taught to believe that the end of the world is very near at hand, and in this the Book of Revelations is followed most literally—each fresh earthquake or pestilence experienced in some part of the world being regarded as a new and definite portent that the end is in sight.

The people are now so definitely rooted in this belief that no provision is made for their future; no young coconuts or breadfruit-trees have been planted, and the same applies to the timber of the island, which has been continually felled for the building of their homes and boats without thought of replanting for future needs.

THE EFFECT OF TROPICAL SUNLIGHT ON THE DEVELOPMENT OF BONES OF CHILDREN IN PUERTO RICO. *A Roentgenographic and Clinical Study of Infants and Young Children with Special Reference to Rickets and Related Factors.* U. S. Department of Labor, Children's Bureau Publication No. 217.

By Martha M. Eliot. U. S. Government Printing Office, Washington. 10 cents. 9½ x 5½; v + 122; 1933 (paper).

In a previous investigation, undertaken jointly by the Children's Bureau and the Department of Pediatrics of Yale University, it was found that in a large proportion of cases the bones of infants living in a temperate climate (New Haven, Conn.) showed sooner or later certain minor changes which were interpreted as evidence of slight rickets regardless of the fact that the infants observed had been given what was thought to be an amount of cod-liver oil sufficient to prevent rickets. The present study, of 584 infants living in a tropical country exposed the year round to intense sunlight, was made by the same investigators to determine whether or not the roentgenographic changes usually interpreted as signs of slight rickets should not be regarded as physiological variations of normally growing bone. After working over the clinical and x-ray records of both the New Haven and Puerto Rico studies, Dr. Eliot and her co-workers were able to conclude that rickets is practically absent in the tropical country, and that the bone changes previously believed to be signs of early or mild rickets are probably correct. From a scientific viewpoint it is difficult to overestimate the value of work of this character. The dividing line between the limits of physiological normality and early pathology is so nebulous and knowledge concerning it is of such importance in almost every field of medical practice that every contribution is of the greatest moment. A short summary report of the paper under review will be found in the *American Journal of Diseases of Children*, Vol. 46, p. 1237.



THE MIND OF CHINA.

By Edwin D. Harvey. Yale University Press, New Haven. \$3.50. 9½ x 6½; xi + 321; 1933.

This is a fundamental contribution to studies on the Chinese. The author, long a resident of China as Professor of Sociology at the College of Yale-in-China, at Changsha (Hunan Province) has had unusual opportunities to observe and study the social system of the Chinese, the influence which their profound faith in ancestor worship has upon their daily lives and customs, their extraordinary dependence on every sort of magic and their belief in the "existence of another world of spirits, a shadowy but real counterpart of life here on earth." Underdevelopment of the industrial and economic arts and overgrowth in population are two of China's most serious problems. Both of these are deeply conditioned by an inveterate animism. Renunciation of the philosophy of animism and the acceptance of the obviously effective materialism and industrialism of the West is the essence of the temper of Young China today. The masses (nearly one quarter of the world population) have merely turned the new expressions into the old animistic molds. However, a collapse of the old way of thinking and living is bound to come with the new education, the growth of railroads and industry; and because of this China will be faced with a problem of immense complexity. A new philosophy of living must be evolved. The volume is copiously documented and is indexed.



THE LIFE OF A FOSSIL HUNTER.

By Charles H. Sternberg. Charles H. Sternberg, 4046 Arizona St., San Diego, Calif. \$1.75. 7½ x 5½; xiii + 286; 1931.

HUNTING DINOSAURS in the Bad Lands of the Red Deer River, Alberta, Canada. A Sequel to The Life of a Fossil Hunter.

By Charles H. Sternberg. Charles H. Sternberg, 4046 Arizona St., San Diego, California. \$1.75 [Both books for \$3.00]. 7½ x 5½; xv + 254; 1932.

Both of these books are reprints. *The Life of a Fossil Hunter* (first printing 1909) deals with the author's wide experience in collecting in the western part of the United States. Hunting for fossils in the seventies and eighties involved far more

than patiently searching for fruitful places to excavate. It meant danger from hostile Indians, days with little or no food, narrow escapes from drowning, etc. For eight seasons Sternberg worked with Cope in the field. This part of the book will perhaps be of the greatest interest to biologists as he writes most entertainingly of Cope and their joint experiences which were often of a thrilling character. *Hunting Dinosaurs* (first printing 1917) is a sequel to *The Life of a Fossil Hunter*. After 1912 the author and his three sons spent much time in the Red Deer region in Alberta where are to be found the richest Cretaceous fossil fields in the world.

Neither of these books is devoted merely to the author's experiences in hunting fossils. They contain much information concerning fossil beds and their contents, the manner of collecting, description and illustration of findings and methods of preparing specimens for exhibitions. Many of the finest specimens of extinct mammals in the American Museum of Natural History, in the Victoria Memorial Museum at Ottawa, as well as in various European museums are due to the enthusiastic labors of Sternberg and his assistants. The books can be recommended for general libraries, particularly high school libraries. They open up a fascinating field for embryonic naturalists. Both volumes are abundantly illustrated and indexed.



URBAN SOCIETY.

By Noel P. Gist and L. A. Halbert.
Thomas Y. Crowell Co., New York. \$3.50.
7½ x 5½; xv + 724; 1933.

This is a study of the growth and characteristics of American cities and their populations. It is less concerned with the possibilities for uplift than it is with the detailed description and interpretation of these curious animal aggregations. It is, quite literally, a study in human ecology and its plan and method are based to a large extent on ecological concepts. The study is carried out with thoroughness and considerable literary skill. The kind of information conveyed by case histories and crime statistics is not represented here;

the emphasis is on the social and economic factors that influence the founding and growth of cities, on migrations to, from, and within cities, and on the effects the peculiar conditions of city life have had on human behavior. The authors have made frequent and effective use of long quotations from sociological studies of particular cities, and their data, on which charts and tables are based, are recent enough to show some of the trends of cities during the depression. It will make a good college textbook but it deserves a wider sale than that. There are a considerable number of thoughtful people whose contacts with city life have been neither close enough nor of long enough duration to give them a basis for understanding the system of coöperative competition that underlies urban life, and they should find this book useful in this respect. There are annotated bibliographies at the end of each chapter and good indexes, one for subjects and one for names of cities.



THE EMPTY QUARTER, *being a Description of the Great South Desert of Arabia Known as Rub 'al Khali*.

By H. St. J. B. Philby. Henry Holt and Co., New York. \$4.00. 8½ x 5½; xxiv + 432 + 3 folding maps; 1933.

The journey of which this book is a narrative was not Mr. Philby's first exploration of the interior of Arabia. In 1917 he had crossed the peninsula from the Persian Gulf to the Red Sea—the first European since Sadlier, a century before, to make the journey—and in 1918 he had explored the Jabal Tuwaiq as far as the Wadi Dawasir but had been forced to turn back regretfully without penetrating the Rub'al Khali or Empty Quarter, the great southern desert of Arabia, "perhaps the largest blank on the map outside the Polar regions." Early in 1932 Ibn Sa'ud made him leader of an expedition which crossed the desert from the Persian Gulf to its southern border and thence westward through its most desolate portion to Wadi Dawasir. On the first part of the journey there were occasional wells, covered to protect them from the shifting sands,

but for the last 375 miles the party had to depend entirely on the water that they carried with them. The supposed ruins of the legendary city of Wabar which they visited turned out to be a meteorite crater. Appendices give reports on the meteorites and silica glass found there as well as on other geological, zoölogical and botanical specimens collected by Mr. Philby. The book also contains an index and excellent maps of the route of the expedition. This is an exciting book of adventure as well as a first rate narrative of an important scientific exploration.



ANCIENT AZTALAN. *Bulletin of the Public Museum of the City of Milwaukee Vol. XIII.*

By S. A. Barrett. *Milwaukee Public Museum, Milwaukee.* \$7.00. 10½ x 7; 602; 1933 (paper).

The ancient earth-works at Aztalan, situated in south-eastern Wisconsin, are among the more important archaeological sites in the United States. Although definite knowledge of their existence dates from the Black Hawk War in 1832, little actual, organized exploration and excavation has been done, with the exception of the survey made in 1850 by Dr. O. A. Lapham, until 1919 when the author of this book began his investigations.

The principal features of the site are the ridge surrounding it, the remains of a stockade, and numerous pits and mounds, only one of which yielded a burial that could be considered authentic. It had long been held that this was a ceremonial spot, but the author abandons this theory on the evidence he has collected and holds the view that it served the more prosaic purposes of defense and utilitarian service. He likewise discards the belief that the ancient inhabitants of Aztalan knew the art of making brick. His assumption is that native clay, mixed with grasses, was used to line the stockade to make it stronger as a defense, and that when it was burned, presumably by enemies, the clay baked and broke off in "bricks"—lumps irregular in form.

This publication is well illustrated with maps showing the present topog-

raphy of the site, as well as those made by Dr. Lapham, and many excellent photographs of the earth-works and their contents. The author has also provided a bibliography of seven pages and an index.



HEREDITY AND ENVIRONMENT. *Studies in the Genesis of Psychological Characteristics.*

By Gladys C. Schwesinger. Edited by Frederick Osborn. *The Macmillan Co., New York.* \$4.00. 9½ x 6½; ix + 484; 1933.

This is a critical compendium of the studies made to determine the relative influence of heredity and environment on the development of personality and intelligence. Its value lies in the clarity of the author's views and her ability to take full cognizance of all the more important investigations.

Splitting the psychological characteristics into intelligence and personality is, as the author admits, arbitrary and evidently done only for the purpose of considering the so-called intelligence tests separately from general psychological theories. With regard to the intelligence tests, the author is rather diffuse but complete in the examination of all the literature. Her conclusion is that they are "valid and reliable," but she immediately adds: "Since many extravagant and even bizarre claims have at times been made on such topics as group differences in intelligence . . . it is essential in interpreting such data that a proper perspective be kept." This sober outlook is characteristic of the objectivity of the book.

The part that treats of personality is, compared to the other, very schematic though in no way incomplete. We do not find here the same thorough analysis as for the intelligence tests.

Finally, the author arrives at the only conclusion possible, that is, that the investigations so far conducted cannot be said to have found an answer to the question.

This volume makes an excellent textbook and will be useful for all students of the subject.

THE AMERICAN ABORIGINES. *Their Origin and Antiquity.*

A Collection of Papers by Ten Authors, Assembled and Edited by Diamond Jenness. University of Toronto Press, Toronto. \$2.50. 9½ x 6½; 396; 1933.

The ten papers in this volume, all by recognized experts in their respective fields, make an extremely valuable symposium on the present status of knowledge about the American Indian. While it is impossible here to review the book in detail some of the outstanding conclusions may be mentioned. W. A. Johnston is of the opinion that western migration routes to North America have been open for 25,000 to 30,000 years, much longer than any possible route in the north-east. Alfred S. Romer holds that there is no paleontological evidence suggesting the presence of man in North America earlier than the withdrawal of the last Pleistocene ice sheet. On archeological grounds N. C. Nelson reaches the same conclusion. E. A. Hooton concludes a brilliant essay on the thought that the American race is a composite race "composed of heterogeneous strains welded together by mixture." Clark Wissler is of opinion that the great variety of cultures and of traits in the New World has obscured whatever may have been transferred directly from the Old World. Roland B. Dixon refuses to allow any of the claims made for diffusion of cultures across the southern Pacific to South America.

The value of the book is seriously impaired by the absence of an index.



660 RUNAWAY BOYS. *Why Boys Desert Their Homes.*

By Clairette P. Armstrong. Richard G. Badger, Boston. \$3.00. 8 x 5½; 208; 1933. This book consists essentially of a statistical analysis of case histories, from the Children's Court of New York City, of 660 boys charged with deserting their homes. The various factors reviewed include, among others, age, intellectual ability, physical defects, nationality, education, economic status, and home con-

ditions. Thus it was found that runaway boys have an average age of approximately 13 years and an average I. Q. of 77.7; that fifty per cent of them have nervous habits such as enuresis, masturbation, temper-tantrums, and so on; that seventy-five per cent are of foreign or mixed parentage; that fifty per cent are graded above their inherent capacities in school; that twenty per cent have both parents employed; that only forty-five per cent have both parents living and living together; that thirty per cent have either a step-mother or step-father. An interesting chapter is devoted to the boys' reasons for leaving home. Of these, excessive beatings, fear of beating and punishment, and a hatred of school or school teacher are given in over fifty per cent of the cases. It is questionable whether the subtitle of the book has been appropriately chosen.



AN ASTRONOMER'S LIFE.

By Edwin B. Frost. Houghton Mifflin Co., Boston. \$3.50. 8 x 5½; xi + 300; 1933.

This is an interesting and stimulating autobiography of a distinguished astronomer, who had the devastating misfortune to go blind at the zenith of his professional career. The simple yet lofty courage with which Professor Frost met this calamity has been an inspiration to his colleagues and friends. His whole life exemplifies and illustrates the traditional virtues and abilities of the New England stock from which he stems. The Frost family, with its record of achievement in scholarly pursuits, is a perfect paradigm for the eugenicist.

Professor Frost writes with clarity and charm, and his life has been an interesting one. We recommend this book strongly to the general reader as well as to the scientific man. Like a great many astronomers of this day and age Professor Frost leans in his philosophic thinking towards a vaguely mystical sort of deism, which we fear will be somewhat unsympathetically viewed by the younger generation of hard-boiled, wholly materialistic biologists.

THE CONQUEST OF A CONTINENT or *The Expansion of Races in America.*

By *Madison Grant*. Charles Scribner's Sons, New York. \$3.00. 8½ x 6; xv + 393; 1933.

The thesis of this history of the United States is that Protestant Nordics were not only the best immigrants this country ever received, its best soldiers, and its best citizens but they were so far in the majority during its colonization and up until the Civil War that they alone are the founders of the nation. No other group has made any significant contribution of a beneficial sort to our culture according to Grant, and it is the duty of Protestant Nordics to take immediate steps to preserve their supremacy, among other things by putting a stop to all further immigration, deporting as many aliens as possible, and putting into effect a number of eugenic proposals. The plan of the book is to classify each group of immigrants according to its racial composition, and to trace the movements of its members and their descendants as they migrated from state to state, and to present a racial survey of the 48 states and of the Latin-American countries to the south. There are about a dozen maps, a bibliography, and an index. Every professional flag-waver will want a copy.

**FLIGHT INTO AMERICA'S PAST. *Inca Peaks and Maya Jungles.***

By *Marie Beale*. G. P. Putnam's Sons, New York. \$3.50. 9½ x 6½; xv + 286; 1933.

A travel book of considerable interest, by an amateur archeologist. Mrs. Beale writes most entertainingly of her trip, mostly by airplane, from Buenos Aires across the Andes to Santiago and then into the land of the Inca. One never ceases to marvel that Cuzco, the sacred city of the Inca, situated high in the Andes and seemingly almost inaccessible to the European invaders, should have become a Spanish town within fifty years of Columbus' great discovery. Inca rule was paternalistic. Close communication was kept up throughout the vast area by well built foot ways. It is said that fish from the ocean could be delivered in Cuzco in

twenty-four hours. Now by train it takes fifty or more. The author's interest in early Peruvian history led her to visit many places which disclose the high development of Inca civilization and the superimposed Spanish culture. After Lima she went to Guatamala and Yucatan and visited Mayan ruins.

Her book is profusely illustrated, mostly with her own photographs, which are excellent. A bibliography is included but there is no index.

**FROHE LEBENSARBEIT. *Erinnerungen und Bekenntnisse eines Hygienikers und Naturforschers.***

By *Karl B. Lehmann*. J. F. Lehmann, München. 4.50 marks (paper); 6 marks (cloth). 8½ x 5½; 328; 1933.

Karl Bernhard Lehmann, one of the pioneers in the movement of public health and hygiene in Germany and one of the founders of modern bacteriology, offers us in this book the story of a long life, spent in arduous yet joyous labor. He tells us of his happy school-years in Zurich during the sixties and seventies of the past century; of his years of apprenticeship under Pettenkofer and Koch in Munich and Berlin, and of his 45 successful years as Professor of Hygiene in the medical faculty of the University of Würzburg. Professor Lehmann is far removed from being a mere reporter. There is not a 'dry' page in the whole book. He gives us exquisite and telling character sketches of his many friends and co-workers, and fine descriptions of the countries he lived in or visited. Furthermore, he defines his position with regard to public health, scientific investigation, education, literature, art, politics, the state and destiny of his country, and religion.

It is, in short, a most refreshing and stimulating book, filled with wisdom and grateful optimism.

**THE GREAT DOCTORS. *A Biographical History of Medicine.***

By *Henry E. Sigerist*. Translated from the German by *Eden and Cedar Paul*. W. W.

Norton and Co., New York. \$4.00. 8 $\frac{1}{2}$ x 5 $\frac{1}{2}$; 436; 1933.

The sub-title indicates the contents of this extremely interesting book, which is a translation from the second German edition. The great doctors are those whose creative work or teachings have had an important part in the evolution of medicine. Fifty-three names (excluding those linked with mythology) are in the list, beginning with Hippocrates and ending with Osler. Briefly but vividly, the lives and works of each of these is in review and the part that each one played in furthering the progress of medicine. Excellent reproductions of portraits are included in the work; also a bibliography of the more important general treatises on the history of medicine and kindred topics, and special works on great doctors. The volume is indexed.



THE BANTU TRIBES OF SOUTH AFRICA. *Reproductions of Photographic Studies. Vol. II, Section III, Plates LIII-LXXVIII. The Suto-Chuana Tribes. Sub-Group III. The Southern BaSotho. With an Introductory Article on the Southern BaSotho and Descriptive Notes on the Plates, by G. P. Lestrade, and a Bibliography of the Southern BaSotho, by I. Schapera.*

By A. M. Duggan-Cronin. Deighton, Bell and Co., Cambridge. 21 shillings. 11 $\frac{1}{2}$ x 8 $\frac{1}{2}$; 24 + 26 plates; 1933 (paper).

Section III of Volume II of this valuable anthropological study, previous sections of which have been noticed in earlier numbers of this REVIEW, contains a short introductory article on the southern BaSotho, a bibliography of 10 pages, and 26 excellent photographs showing the physical type of the people, as well as their dress, architecture and customs. Under the guidance of an unusually enlightened group of missionaries who have preserved what was good in the old and adapted it towards the new, native writers have been encouraged to produce "works of a literary nature, of outstanding merit among the literary productions of the modern type among the South African Bantu."

THE CHILD, THE FAMILY AND THE COURT. *A Study of the Administration of Justice in the Field of Domestic Relations. General Findings and Recommendations. U. S. Department of Labor, Children's Bureau Publication No. 193 (revised edition).*

By Bernard Flexner, Reuben Oppenheimer, and Katharine F. Lenroot. U. S. Government Printing Office, Washington. 10 cents. 9 $\frac{1}{2}$ x 5 $\frac{1}{2}$; vi + 100; 1933 (paper).

This report recommends the nation-wide establishment of only one type of court to exercise jurisdiction over all cases directly or indirectly regarding children. This court would take the place of the present juvenile courts, family courts, etc., and also extend its activity to include the work now done by the humane societies, social agencies, etc. This consolidation of judicial power is proposed especially to avoid the overlapping of jurisdiction frequently observed in the cases dealt with by these courts and agencies.



OUR FOREFATHERS. *The Gothonic Nations. A Manual of the Ethnography of the Gothic, German, Dutch, Anglo-Saxon, Frisian and Scandinavian Peoples. Volume II.*

By Gudmund Schütte. The Macmillan Co., New York. \$9.50. 9 x 6 $\frac{1}{4}$; xvi + 482 + 20 plates; 1933.

The promised second volume of this excellent series on ethnic groups is now ready. The first volume was noticed in Volume 5 of this REVIEW. This part gives accounts of individual Gothonic tribes (Germanic nations) under the same subject headings as were used in the first volume for the Gothonic nations as a whole, —at least, as far as is possible. This is a detailed and scientific study but it is full of interesting details, such as the seven reasons why England came to be called England rather than some name based on the Saxon element in the population. The descriptions of the primitive architecture of the various tribes are also interesting to the layman.

THE HAND OF MAN. *A Practical Treatise of the Science of Hand Reading Dealing in Detail with its Psychological, Sexual, Superstitious and Medical Aspects.*

By Noel Jaquin. Faber and Faber, London.
12s. 6d. net. $8\frac{1}{2} \times 5\frac{1}{2}$; 268; 1933.

New and profitable horizons are here disclosed for the practitioners of the ancient art—pardon! science—of palmistry. It is possible by careful reading of the hand to diagnose the physical ills of an individual, so the author says. For example, diagnosis of cancer in its early stages, or even before it appears, is evidently child's play for Mr. (or is it Professor?) Jaquin. Notwithstanding his great ability he is really modest. There is, though, brief mention of cases in which the physicians had failed at first and only following the hand reading was the true diagnosis made. We sympathize with the poor physicians. How is it possible for them to make a diagnosis when they have not the knowledge acquired through palmistry?



IN WILD NEW BRITAIN. *The Story of Benjamin Danks, Pioneer Missionary. From His Diary.*

Edited by Wallace Dean. Angus and Robertson, Sydney. 6 shillings net. $7\frac{1}{4} \times 4\frac{1}{2}$; xi + 293; 1933.

The Reverend Mr. Benjamin Danks and his wife gave eight years of their youth in the attempt to convert the natives of New Britain to Methodism. From 1875 to 1886 they lived and worked in that savage country and here are recorded their hardships and achievements. One cannot but admire their fortitude and that of all those dedicated to such a cause.

There are a few interesting accounts of local customs, mention of conflict with traders, but in style and viewpoint the book is strictly ecclesiastical and intended to fire missionary zeal in those of the same faith and profession.



THE DIFFUSION OF CULTURE.

By G. Elliot Smith. Watts and Co., London. 7s. 6d. net. $7\frac{1}{2} \times 5$; x + 244; 1933.
In this book the arch protagonist of the

diffusion of culture from a single center, with Egypt as "the pioneer in the invention of civilization," makes a vigorous endeavor to prove the soundness of his position from the very evidence provided by the writings of the antagonists of this theory.



THE EUGENIC PREDICAMENT.

By S. J. Holmes. Harcourt, Brace and Co., New York. \$2.00. $8 \times 5\frac{1}{4}$; xi + 232; 1933.

This is an elementary exposition of the principles and aims of eugenics and the genetic facts from which they are derived. In form and content it differs very little from the general run of propagandist literature on the subject.



ARCHIV FÜR BEVÖLKERUNGSWISSENSCHAFT (VOLKSKUNDE) UND BEVÖLKERUNGSPOLITIK. IV. Jahrg., Heft 1.

Edited by Kurt Vowinkel. S. Hirzel, Leipzig. 10 marks per volume of six numbers; 2 marks, single copy. $9\frac{3}{8} \times 6\frac{5}{8}$; 80; 1933.

We welcome this journal dealing with population problems and recommend it to our readers interested in the subject.



JUVENILE-COURT STATISTICS, 1931. *Based on Information Supplied by 92 Courts. Fifth Annual Report. United States Department of Labor, Children's Bureau Publication No. 222.*

U. S. Government Printing Office, Washington. 10 cents. $9\frac{1}{8} \times 5\frac{1}{4}$; 11 + 62; 1933 (paper).

The report for the year 1931 presents much the same situation as that for the previous year (cf. this REVIEW, Vol. VIII, p. 114).



THE COUNTY AS AN ADMINISTRATIVE UNIT FOR SOCIAL WORK. *United States Department of Labor, Children's Bureau Publication No. 224.*

By Mary R. Colby. U. S. Government Printing Office, Washington. 5 cents. $9\frac{1}{2} \times 5\frac{1}{2}$; v + 48; 1933 (paper).



ZOOLOGY

BELAUSCHTES LEBEN. *Kleine Kreatur in Wasser, Busch und Halm.*

By Karl O. Bartels. Hugo Bermühler, Berlin-Lichterfelde. 3.90 marks (paper); 4.80 marks (cloth). $10\frac{1}{2} \times 7\frac{1}{2}$; xi + 182; 1934.

Here are 120 pages of extraordinary reproductions of photographs of small animals shown in various stages of active life in natural habitats. The reproductions are technically excellent, giving full force to the beauty of the subjects. The phases of behavior are emphasized by serial pictures such as illustrate the stages of the engulfment of a minnow by a coelenterate, the emergence of a damselfly, the mating of mantids in which the male is finally eaten by the female, a caterpillar spinning its cocoon, and many others equally interesting. The pictures are arranged so that biological forms take a related order. Each picture has a title and descriptive notes accompanying it. After the pictures there follow about fifty pages of text in which are given interesting comments on the biology of the general classes. The pictures representative of the class are also discussed in the order in which they are arranged in the first part of the book. An alphabetical index is given last. This book will be valued by the scientific biologist as well as by the esthetic nature lover, and it will probably attract many who are habitually indifferent to the less obvious occurrences in nature.



DIPTERA OF PATAGONIA AND SOUTH CHILE. *Based Mainly on Material in the British Museum (Natural History). Part IV. Empididae.*

By J. E. Collin. British Museum (Natural History), London. 15 shillings net. $8\frac{1}{2} \times 5\frac{1}{2}$; viii + 334; 1933.

The first volume of this series by Alexander, noticed in Volume VI of the REVIEW, gives a brief description of the collecting trip where specimens described here were gathered. The collecting was done by F. W. Edwards of the British Museum and R. C. Shannon of the Bacteriological Institute of the National Department of Hygiene, Argentina. There were about 30,000 specimens of Diptera taken which eventually will be described in seven volumes. This section by Collin, although Part IV, is the second to be completed. There were 247 species of Empididae represented in the collection, of which 198 are new to science. All these and some Empididae from other collections made in the same area are included in the detailed taxonomic description. There is an index.

There appears to be a general tendency for the Empid fauna of any distinct faunal region to develop marked peculiarities of its own, and the Patagonian fauna is certainly no exception, but it will be gathered from the information here given, that, on the whole, it shows a distinctly greater resemblance to the fauna of the South Australian region than to any other.



REPTILES OF THE WORLD. *The Crocodilians, Lizards, Snakes, Turtles and Tortoises of the Eastern and Western Hemispheres. New Revised Edition.*

By Raymond L. Ditmars. The Macmillan Co., New York. \$5.00. $9\frac{1}{2} \times 6$; xx + 321 + 89 plates; 1933.

A new edition, revised and containing much new material, of a work which has been widely accepted as standard in the study of reptiles (first edition 1910). The nomenclature has been completely brought up to date and the text enlarged to include all recent important discoveries. The work, however, departs considerably from the hand-book type. The author presents in popular manner a general survey of the reptiles of the world and includes many of his own methods in capturing, feeding and treatment of animals in captivity. The 89 excellent photographic plates collected at the end of the volume are valuable for identification purposes. There is an index.

GULLIVER IN THE BUSH. *Wanderings of an Australian Entomologist.*

By H. J. Carter. Angus and Robertson, Sydney. 6 shillings. 7½ x 4½; v + 234; 1933.

Gulliver, in the person of the author, is an Australian entomologist and natural historian who writes of his many experiences while rambling over the Australian continent. A chapter (or more) is devoted to each of the divisions of the Commonwealth including the island of Tasmania. The author stresses his personal experiences while collecting in the various regions and gives the reader many interesting annotations about insect life. The book is of interest to the American reader since it gives a familiar insight into the all too unfamiliar Australia. Mr. Carter does not hesitate to tell of his companions and various people met with on his travels, which frequently adds zest to the reading. Some readers will find many of the references to insect life too anthropomorphic to suit their taste.

**BIOLOGY OF BRACHYMERIA FONSCOLOMBEI (DUFOUR), A HYMENOPTEROUS PARASITE OF BLOWFLY LARVAE.** U. S. Department of Agriculture Technical Bulletin No. 365.

By Raiford A. Roberts. U. S. Government Printing Office, Washington. 5 cents. 9 x 5½; 21; 1933 (paper).

Brachymeria, a chalcid parasite of blowfly larvae, is carefully studied under field conditions. It is found in Europe, Asia, and North America where it most actively parasitizes larvae of the genus *Sarcophaga*. It readily attacks *Synthesiomyia*, *Phoremia*, *Lucia*, and *Calliphora*, but when it attacks the screw-worm, larvae of *Cochliomyia macellaria* Fab., both insects fail to complete development.

The parasite egg is injected into the host larvae, where, upon hatching, it develops within the maggot. After pupation of the host the parasite completely consumes the pupae and then pupates within the host puparium. Eggs from unfertilized females produce only males, and the sex ratios are frequently irregular in progeny from ferti-

lized females. At Uvalde, Texas, eight generations occur during the year, and about one third of the fly larvae in small field carcasses are infested. The parasite might be useful in control of the blowfly population in general, but as a specific agent against the screw-worm it is not recommended.

**MORPHOLOGY OF THE INSECT ABDOMEN. Part II. The Genital Ducts and the Ovipositor.** Smithsonian Miscellaneous Collections, Volume 89, Number 8. (Publication 3219.)

By R. E. Snodgrass. Smithsonian Institution, Washington. 45 cents (free to public libraries). 9½ x 6½; 148; 1933 (paper).

A second monograph on the morphology of the insect abdomen by the leading authority on insect anatomy (Part I. General structure of the abdomen and its appendages). It forms part of a general scheme "to discover the basic plan of arthropod organization that is repeated through the segments, and to see how the special modification in the several body regions of the insect may conform with the structure of a theoretically generalized segment." The author first discusses the general structure of the insect abdomen and the morphology of the gonads and the genital ducts. There follow sections on the ovipositor and associated organs, the ovipositor of Orthoptera, of Hemiptera, and of Hymenoptera. Forty-eight figures accompany the text and a lengthy literature list is given.

**THE NIDIFICATION OF BIRDS OF THE INDIAN EMPIRE. Volume II. Turdidae-Sturnidae.**

By E. C. Stuart Baker. Taylor and Francis, London. 30 shillings net. 8½ x 6; vii + 564; 1933.

In this volume the breeding habits and nests of 403 species and subspecies of Passeres breeding in India are described. The material is arranged by families and subfamilies, and includes the thrushes, shrikes, warblers (including the tailor-bird and

the still more remarkable Ashy wren-warbler), goldcrests, bluebirds, orioles, grackles, and starlings. The classification agrees for the most part with that found in the author's earlier volumes on these birds in the *Fauna of British India* series. Although much detailed information is supplied in summary form, Mr. Baker's gift of style makes the book very readable. An index of common and scientific names is provided, but there is no bibliography although much of the descriptive material has been taken from other writers.



THE ECOLOGY OF ANIMALS.

By Charles Elton. Methuen and Co., London. 3s. 6d. net. 6 $\frac{1}{2}$ x 4 $\frac{1}{2}$; vii + 97; 1933.

This little book belongs in a series of monographs designed to give brief but authoritative accounts of the present state of knowledge in biological subjects. The author is Director of the Bureau of Animal Population of the Department of Zoology and Comparative Anatomy in Oxford University. Teachers, students and the general reader will find the volume useful in obtaining general information on economic problems, on the scope of animal ecology, ecological surveys, animal interrelations and habits, densities of animal populations and their rates of increase and fluctuations in numbers. A lengthy literature list is given and there is an index.



THE GROWTH OF SOME YOUNG RAPTORIAL BIRDS. *University of California Publications in Zoology, Volume 40, No. 4.*

By E. Lowell Sumner. *University of California Press, Berkeley.* 10 $\frac{1}{2}$ x 6 $\frac{1}{2}$; 32; 1933 (paper).

Seven young owls and three young eagles were kept under observation in the laboratory and in the nest during their growth period. Especial attention was given to the development of down and feathers and a number of photographs are given to illustrate the types of plumage and the appearance of the birds. Measurements of body weight, feather length, and lengths of humerus and ulna were made; all of these

measurements fall along sigmoid growth curves. It appears that raptorial birds eat proportionately less than passerine birds.



TERMINOLOGY OF TYPES.

By Donald L. Frizzell. *The American Midland Naturalist*, Vol. XIV, No. 6, pp. 637-668, 1933.

Another earnest attempt to standardize the terminology of taxonomy. A list of 233 terms is appended giving definitions with the authorities for them. By means of different sizes and styles of type used in this list one can tell which terms the author recommends; which he considers less desirable but "available for use;" and which are objectionable. There is a short general bibliography as well as the references pertaining to the definitions.



BUNYIPS AND BILLABONGS. *An Australian Out of Doors.*

By Charles Fenner. Angus and Robertson, Sydney. 6 shillings net. 7 $\frac{1}{2}$ x 4 $\frac{1}{2}$; xvi + 241; 1933.

An interestingly written series of nature studies on a wide variety of Australian animals, folklore, and curiosities. Many myths concerning natural phenomena are used to create interest. These are ultimately followed to their origin in nature without loss of the feeling of wonderment. The young reader who enjoys exploratory information about natural things will make a delighted discovery in this book, and there is no dearth of ideas that challenge adult curiosity.



OBSERVATIONS ON THE THERMAL DEATH POINTS OF ANASTREPHA LUDENS (LOEW). *U. S. Department of Agriculture Technical Bulletin No. 400.*

By Hugh H. Darby and E. M. Kapp. U. S. Government Printing Office, Washington. 5 cents. 9 $\frac{1}{2}$ x 5 $\frac{1}{2}$; 18; 1933 (paper).

This brief paper is concerned (1) to see whether insect protoplasm is subject to heat coagulation at temperatures similar

to those which affect other animals, and (2) to determine what climatic conditions can be expected to limit or prevent the establishment of *Anastrepha ludens* (a Trypetid fly) in regions as yet uninfested. The authors, on the basis of their data, answer the first question affirmatively.



THE PULSATORY CYCLE OF THE CONTRACTILE VACUOLES IN THE OPHRYOSCOLECIDAE, CILIATES FROM THE STOMACH OF CATTLE. *University of California Publications in Zoology, Volume 39, No. 11.*

By Ronald F. MacLennan. *University of California Press, Berkeley.* 60 cents. 10½ x 6½; 46; 1933 (paper).

A careful study of the cyclic changes undergone by the contractile vacuole of certain ciliate protozoans (the Ophryoscolecidae) shows that the vacuole has three characteristic phases in its cycle, the resting period, systole and diastole. Morphological changes associated with the vacuole and its protoplasmic surroundings are described. A good bibliography is appended.



SUGGESTIONS FOR PHEASANT MANAGEMENT IN SOUTHERN MICHIGAN.

By Howard M. Wight. *Department of Conservation, Lansing, Mich.* 9 x 6½; 25; 1933 (paper).

The material in this pamphlet, intended primarily for farmers and other landowners who wish to increase the supply of pheasants, is based on a five years' study of the habits of these birds by the School of Forestry at the University of Michigan. Suggestions, with directions and illustrations, are given for the improvement of roadsides, woodlots, pasture-land, etc., with the breeding habits of pheasants in mind, the planting of food patches, and predatory control.



ANNUAL REPORT OF THE DIRECTOR OF THE MUSEUM OF COMPARATIVE ZOOLOGY AT HARVARD COLLEGE TO THE PRESIDENT OF HARVARD COLLEGE FOR 1932-1933.

By Thomas Barbour. *Museum of Comparative Zoology, Cambridge.* 9½ x 6; 69; 1933 (paper).

This includes brief reports by the director of the Museum, Thomas Barbour, and by seventeen curators of different departments of the museum, a list of publications (109 titles) issued during the year August 1, 1932 to July 31, 1933, and a brief account of the use of the income of the Museum's invested funds.



WINTER FEEDING OF WILD LIFE ON NORTHERN FARMS. *U. S. Department of Agriculture Miscellaneous Publication No. 159.*

By Wallace B. Grange. *U. S. Government Printing Office, Washington.* 5 cents. 9½ x 5½; 12; 1933 (paper).

A discussion of the need and methods for winter feeding to conserve wild life. Organization of campaigns to insure needed food at the right time, the proper type of food for various birds and animals, and the most economical methods of supplying food and winter protection are considered. Several interesting figures are given which show wild birds making use of provided food and shelter.



THE DINOFLAGELLATA: THE FAMILY HETERODINIIDAE OF THE PERIDINIOIDAE. *Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in Charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross," from October, 1904, to March, 1905, Lieut.-Commander L. M. Garrett, U. S. N., Commanding. Memoirs of the Museum of Comparative Zoology at Harvard College, Vol. LIV, No. 1.*

By Charles A. Kofoid and Alastair M. Adamson. *Museum of Comparative Zoology of Harvard College, Cambridge.* \$6.50. 12 x 10; 136 + 22 plates; 1933 (paper).

The family Heterodiniidae comprises a number of relatively rare species of the Peridinioidae restricted to warm temperate and tropical seas. They are only sparsely represented in the surface waters and most of the 35 species, of which five are new, described and figured here were taken at 300 fathoms.

THE LIFE HISTORIES AND ECOLOGY OF JACK RABBITS *LEPUS ALLENI* AND *LEPUS CALIFORNICUS* SPP., IN RELATION TO GRAZING IN ARIZONA. *College of Agriculture, Agricultural Experiment Station Technical Bulletin No. 49.*

By Charles T. Vorhies and Walter P. Taylor.
University of Arizona, Tucson. 9 x 6½; 120; 1933 (paper).

A good account of the life history and habits of the jack rabbits, with remarks on the natural enemies, parasites and methods of control.



THE CANADA JAYS OF NORTHERN IDAHO. *Transactions of the San Diego Society of Natural History, Vol. VII, No. 25.*

By Alden H. Miller. *San Diego Society of Natural History, San Diego, Calif.* 10½ x 6½; 9; 1933 (paper).

TRANSPPOSED HINGE STRUCTURES IN LAMELLIBRANCHS. *Transactions of the San Diego Society of Natural History, Vol. VII, No. 26.*

By W. P. Popenoe and W. A. Findlay.
San Diego Society of Natural History, San Diego, Calif. 10½ x 6½; 14 + 1 plate; 1933 (paper).

MEN AND BIRDS IN JOINT OCCUPATION OF NATIONAL PARKS.

By George M. Wright. *The Condor, Vol. XXXV, November 1933, pp. 213-218.*

REVIEW OF THE RECENT MAMMAL FAUNA OF CALIFORNIA. *University of California Publications in Zoology, Volume 40, No. 2.*

By Joseph Grinnell. *University of California Press, Berkeley.* \$1.25. 10½ x 6½; 64; 1933 (paper).

MAMMALS OF THE POCATELLO REGION OF SOUTHEASTERN IDAHO. *University of California Publications in Zoology, Volume 40, No. 3.*

By Wayne B. Whitlow and E. Raymond Hall. *University of California Press, Berkeley.* 35 cents. 10½ x 6½; 42; 1933 (paper).



BOTANY

RECENT ADVANCES IN THE STUDY OF PLANT VIRUSES.

By Kenneth M. Smith. *P. Blakiston's Son and Co., Philadelphia.* \$4.00. 7½ x 5½; xii + 423; 1934.

In the preface the author states that

The present volume has . . . been written in the hope that it will serve the dual purpose, first of giving a fairly comprehensive survey of the present position of the knowledge concerning these interesting agents (plant viruses), and secondly of acting as a students' reference book until the progress and correlation of knowledge allow a more comprehensive treatise to be written. For the latter reason, certain subjects have been dealt with in greater detail than is usual in a book of this type.

The volume will be found most useful to those working in this field. The technique of studying plant viruses is described in detail, as well as the diseases they cause. Comparisons are drawn in the behavior of the plant and animal viruses so far as is possible in the present development of knowledge concerning them, and profitable lines of future work are indicated. Each section concludes with a lengthy literature list. The volume is well illustrated and contains author and general indices.



THE PEOPLE'S FORESTS.

By Robert Marshall. *Harrison Smith and Robert Haas, New York.* \$2.00. 8½ x 5½; 233; 1933.

The author first discusses the great devastation of our forests from the time of the early settlements up to the present and the usefulness of forests as raw material, for soil and water conservation, and for recreational purposes. The latter part of the book is concerned with a discussion of various types of ownership and control of forests and "their effect on the forest, on efficient land use, on the workers, on the consumers and on the dependent communities." In the final chapter is given an outline for a national program of forest conservation. The author is a professional forester who in 1932 collaborated with the Forest Service in the preparation of a comprehensive report on the nation's forests. The book contains a list of references and is indexed.



PFLANZENTHERMODYNAMIK.

By Kurt Stern. *Julius Springer, Berlin.* 32 marks (paper); 33.20 marks (cloth). 8½ x 5½; xi + 412; 1933.

Professor Stern makes no claim that his book will be easy reading, but no introduction to thermodynamics is likely to be easy. The first 200 pages are intended to teach biologists enough about thermodynamics to enable them to understand its applications to biology. The second part is a discussion of the thermodynamic aspects of a number of plant processes, permeability, the ascent of sap, respiration and other metabolic processes, electrical phenomena and surface phenomena. The text is clearly written and it is an important contribution to physiological literature. It is well indexed, and in the literature citations it is interesting to note that Americans are well represented.



FORTSCHRITTE DER BOTANIK. *Unter Zusammenarbeit mit mehreren Fachgenossen. Zweiter Band. Bericht über das Jahr 1932.*

Edited by Fritz von Wettstein. Julius Springer, Berlin. 24 marks. 9 $\frac{3}{4}$ x 6 $\frac{1}{2}$; iv + 302; 1933 (paper).

This is the second number of an annual review of botany written in the same fashion, and as successfully, as the *Annual Review of Biochemistry*. The field of botany, not including applied botany, has been very thoroughly covered by seventeen German botanists who discuss the advances made in their respective fields in the year 1932. The bibliographies are extensive and it is worth noting that American work is well represented. It is an indispensable book for every botanical library.



SEX IN THE PLANT WORLD.

By Wilfred W. Robbins and Helen M. Pearson. D. Appleton-Century Co., New York. \$2.00. 7 $\frac{3}{8}$ x 5; xii + 193; 1933.

This survey of reproduction in the plant kingdom is written for people without previous scientific training and accordingly technical terms have been strictly avoided and the story has been told in pictures as far as possible. As popular scientific writing goes it is well done; a historical background of the subject is provided and the discoverers of important phenomena

are mentioned by name. There is less fanciful language than might perhaps have been expected.



QUANTITATIVE BACTERIOLOGY.

By H. O. Halvorson and N. R. Ziegler. Burgess Publishing Co., Minneapolis. \$1.90. 11 x 8 $\frac{1}{2}$; 64; 1933 (paper).

This book provides tables to aid in the solution of equations to determine the probable density of bacteria by the dilution method, the extent of infestation of insects with viruses or bacteria, or other presence-or-absence sampling problems.



LES ASTRAGALUS DU QUÉBEC ET LEURS ALLIÉS IMMÉDIATS. *Contributions du Laboratoire de Botanique de l'Université de Montréal, No. 24.*

By Jacques Rousseau. Institut Botanique, Université de Montréal, Montréal. 75 cents. 9 x 6; 66; 1933 (paper).



MORPHOLOGY

CONTRIBUTIONS TO EMBRYOLOGY. *Volume XXIV, Nos. 139 to 143. Carnegie Institution of Washington Publication No. 443.*

Carnegie Institution of Washington, D.C. \$3.25 (paper); \$4.25 (cloth). 11 $\frac{1}{8}$ x 9; iii + 202 + 31 plates; 1933.

The following papers are included in this publication: (1) Development of behavior patterns and myelinization of the nervous system in the human fetus and infant, by Orthello R. Langworthy. This is the concluding report of a series of observations concerning the development of behavior patterns in young animals correlated with one demonstrable step in the maturation of the neuron, and myelinization of the nerve-fiber.

(2) Development of the vagina in the human fetus, by Arthur K. Koff. The conclusion is reached that "the upper part of the vagina develops from the müllerian ducts, while the lower portion, about one-fifth, is formed from the sinovaginal bulbs

which arise from the epithelium of the urogenital sinus."

(3) Development of the thyroid, parathyroid and thymus glands in man, by G. Louis Weller, Jr. A review of the interrelationships existing between the elements of these organs, and a discussion of how each of the glands assumes its characteristic adult location and architecture.

(4) Histological studies of the menstruating mucous membrane of the human uterus, by G. W. Bartelmez. Seventeen specimens, removed at operation, are described. The study includes clinical data, gross examination of the mucous membrane, general description of the microscopic preparations with especial reference to the indications of a preceding pseudopregnancy, details concerning glandular structure, stroma elements and extravasations, blood-vessels and lymphatics.

(5) Early cleavage stages of the egg of the monkey (*Macacus rhesus*), by Warren H. Lewis and Carl G. Hartman. This account is based on four eggs obtained from the monkey (*Macacus rhesus*) colony of the Department of Embryology, Carnegie Institution of Washington. When recovered one of these eggs was in the two-cell stage, two eggs were in the four-cell stage and one in the 16-cell stage. The two eggs in the four-cell stage were incubated to the six- and eight-cell stage.

All of these papers are beautifully illustrated and thoroughly documented.



HISTOLOGY.

By S. Ramón-Cajal. Revised by J. F. Tello-Muñoz. Authorized Translation from the Tenth Spanish Edition by M. Fernández-Núñez. William Wood and Co., Baltimore. \$8.00. 9 x 5½; xiv + 738; 1933.

A translation of an elementary student's textbook, written by the dean of Spanish histologists, which is widely used in Spanish-speaking universities. It presents a compendium of the investigations of the author and his disciples. The method of instruction differs markedly from that in American schools. During the first year the medical student is given a thorough foundation in cytology, its history and philosophy. The normal histologic topog-

raphy of the individual organs is then taken up, along with the histo-pathology of the same during the second year. The present volume (tenth Spanish edition) is an almost exact literal translation from the Spanish text, so that the nomenclature, phraseology and system will often appear unusual. It is the translator's hope that the reader will be inspired to investigate Spanish medical literature more deeply. The volume is well illustrated. There is an appendix dealing with method of preparation of materials and a detailed index. Dr. Charles H. Mayo contributes a foreword.



AN INTRODUCTION TO THE STUDY OF THE NERVOUS SYSTEM. Second Edition.

By E. E. Hewer and G. M. Sandes. William Heinemann (Medical Books), London. 21 shillings net. 9½ x 7¼; xiv + 147; 1933.

This volume, in its second edition, deals in a compact and logical manner with the anatomy, and to some extent the physiology, of the nervous system. Both the central and autonomic systems are considered. One of the most desirable features of the book is its abundance of several-colored diagrams which should be of assistance in orienting the student with reference to his subject. Another point, worthy of praise, is the highly systematic way in which the subject matter is organized. The volume is an out-and-out textbook and the author has rightly treated the material from just that point of view. The book does not seem to be durably bound and would probably quickly show signs of wear if subjected to the rigors of the laboratory.



THE HISTORY OF STAINING.

By H. J. Conn, with contributions from Lloyd Arnold, A. F. Blakeslee, R. S. Cunningham, S. I. Kornhauser, F. W. Mallory, Eugen Unna. Book Service of the Biological Stain Commission, Geneva, N. Y. \$2.00. 8½ x 5½; 141; 1933.

Much of the advance in histology and

cytology during the past 75 years has been due to the staining of the structures examined under the microscope. This book traces the history of the various biological stains and includes portraits and biographical sketches of Sir John Hill, the first known user of dyes in microscopy, Gerlach, the father of the staining method in histology, Rudolph Heidenhain, Paul Mayer, Unna, Ehrlich, Flemming, Belling and Mann. Bibliographies to the various chapters and an index are included.



PHYSIOLOGY AND PATHOLOGY

ARTERIOSCLEROSIS. *A Survey of the Problem. A Publication of The Josiah Macy, Jr. Foundation. Edited by Edmund V. Cowdry. The Macmillan Co., New York.* \$5.00. 9½ x 6; xvii + 617; 1933.

Leading American and European investigators have contributed to this survey of the problem of arteriosclerosis sponsored by the Josiah Macy, Jr. Foundation. Its purpose is to give a clearer perspective of our present knowledge of the disease and indicate which appear to be the more promising directions to follow in future research.

The different aspects and phases of this problem are outlined in the Introduction by L. Anschoff, and fully developed by the individual contributors in the chapters that follow. These include an excellent historical summary by E. Long; the description of the normal anatomy and physiology of blood vessels (E. V. Cowdry), their physical properties (C. Bramwell) and chemical constituents (A. Policard). The studies on the possible etiological factors are discussed in the chapters on the chemical changes observed (H. G. Wells), the influence of race and climate (P. Stocks), that of nutrition (S. Weise and G. R. Minot), of infections (W. G. MacCallum), of heredity (G. D. Williams), and on the relation of arteriosclerosis to hypertension (F. Lange). W. Ophüls considers the pathogenesis in man and therapeutic measures are outlined in the paper by J. Wykoff. Available statistical data are presented by E. Sydenstricker. There are also

chapters on the incidence of arteriosclerosis in animals (H. Fox) and results of experimental work (N. Anitschow). The incidence and form which this disease takes in certain regions of the body are discussed by such specialists as J. S. Friedenwald, S. Cobb, D. Blain, H. T. Kassner, and E. T. Bell.

In conclusion, the universal opinion is that the work so far is too insufficient and inconclusive to answer the fundamental question of whether this disease can be avoided or remedied.



HISTORY OF CHINESE MEDICINE. *Being a Chronicle of Medical Happenings in China from Ancient Times to the Present Period.*

By K. Chimin Wong and Wu Lien-Teh. The Tientsin Press, Tientsin, China. \$7.50. 9½ x 6½; xviii + 706; no date.

A history of Chinese medicine necessarily resolves itself into two parts. The first (pp. 1-123) is concerned with medicine as an "indigenous and mysterious art." This period extends from the ancient or legendary period (2697-1122 B.C.) through the historical or golden period (1121 B.C.-960 A.D.) and the medieval or controversial (961-1800 A.D.). K. C. Wong, Licentiate in Medicine and Surgery, Hong Kong, is author of this section.

The second part of the book (pp. 127-595) deals with the struggles for supremacy between the old and new forces after Western medicine was introduced into China. Wu Lien-Teh, director of Manchurian plague prevention service and of national quarantine service has written of this epoch. He points out that "To introduce bodily the medicine of Europe and America into China without attention either to the traditional background or to the special needs of the masses would be as unwise as it would be unworkable."

Both sections of the volume make extremely interesting reading and will be of great value to the medical historian. Chronological tables are arranged for both parts, bibliographies, and indexes of persons and subjects. The illustrations, especially those in part one, form a valuable feature of the book.

MENTAL EFFORT in Relation to Gaseous Exchange, Heart Rate, and Mechanics of Respiration. *Carnegie Institution of Washington Publication No. 446.*

By Francis G. Benedict and Cornelia Golay Benedict. *Carnegie Institution of Washington, D. C.* \$1.00 (paper); \$1.50 (cloth). 10 x 6 $\frac{1}{2}$; 83 + 2 plates; 1933.

Seven subjects, six men and one woman, all practically normal in every respect except that one very tall man had a basal metabolism averaging 16 per cent below normal, were used in the experiment. The investigators report that

from a consideration of the various factors measured in our investigation it is concluded that sustained, intense mental effort, consisting chiefly in the multiplication of pairs of 2-digit figures, causes an increase in heart rate, an insignificant, hardly measurable increase in respiration rate, a marked alteration of the character of the respiration, a considerable increase in the apparent total ventilation of the lungs, a small increase in the carbon-dioxide exhalation, a smaller increase (on the average, 4 per cent) in the oxygen consumption and heat production, and a slight increase in the apparent respiratory quotient.

During rest periods between the experiment all factors measured tended to return to original levels.

During the progress of the four consecutive 15-minute periods of mental effort there was no evidence of any greater effect upon the factors measured during the latter periods than during the first periods.

There was no appreciable alteration in the blood supply to the skin of the head. The conclusion is reached that mental effort *per se* is without significant influence upon the energy metabolism and that its study gives no direct evidence of a satisfactory explanation of the feeling of extreme mental and physical fatigue experienced by mental workers following mental effort. The report includes illustrations of the apparatus used in the experiments and 12 tables of data.



THE GROWTH AND GONAD-STIMULATING HORMONES OF THE ANTERIOR HYPOPHYSIS. *Memoirs of the University of California Volume 11.*

By Herbert M. Evans, Karl Meyer, and Miriam E. Simpson, in collaboration with Alexander J. Szarka, Richard I. Pencharz,

Robert E. Cornish and Frederick L. Reichert. *University of California Press, Berkeley.* \$10.00. 12 $\frac{1}{2}$ x 9 $\frac{1}{2}$; xii + 446 + 14 plates; 1933 (paper).

Fourteen more or less distinct papers make up this magnificent and admirably illustrated quarto. The first four, comprising approximately one-half of the book, deal with the technical details of the preparation, purification and biologic characteristics of the growth and the gonad-stimulating hormones. The second four articles are devoted to studies on the effects of the administration of the hormones to hypophysectomized rats. The ninth paper, subdivided into four parts, contains brief reports of recent experimental work on the relationship between the hypophysis and adrenals. Numbers ten and eleven have to do, respectively, with the influence of the gonad-stimulating extract on the tissue metabolism of immature gonads and the respiratory metabolism of rats tested with the growth hormone. The twelfth and thirteenth sections give accounts of the effect of combinations of extracts on the genital system of hypophysectomized dogs. The last, and from a philosophical point of view the most interesting paper, presents evidence that under the influence of long continued injections of the gonad-stimulating fraction, achondroplastic animals (the dachshund) retain their dysplastic characteristics despite great increase in size. Although it may appear unfortunate to those not technical specialists of endocrinology, the authors have refrained, it seems wisely, from giving a general interpretative summary of their work. References are given at the end of each paper and a subject index for the whole volume is included.



AN OUTLINE OF IMMUNITY.

By W. W. C. Topley. *William Wood and Co., Baltimore.* \$6.00. 9 $\frac{1}{2}$ x 6 $\frac{1}{2}$; vii + 415; 1933.

A text-book designed for the advanced student in pathology, bacteriology or hygiene, or more specifically for the pre-clinical student in medicine. Immunity is defined and considered as that which is

better expressed and understood as resistance. This idea implying variability, the author gives in the second chapter typical statistical procedures useful in immunological problems.

The classical concepts, theories and terminology of the field are given in a developmental order, and they are evaluated in terms of up-to-date experimental procedure. By elucidating each concept with specific examples a great deal of essential technical detail is got into the text. Further clarity is gained by extensive use of protocols and diagrams. The concept that segregation through heredity contributes to the variability in immunological reactions is conspicuously absent.

In cases where the biological nature of the therapy is not beyond the controversial stage, as with bacteriophage and many other newly proposed techniques, the author takes an optimistic attitude and spares no labor in abstracting the best authorities.

The book is carefully organized with index, chapter sub-heads and topic titles. Each chapter has a summary and an extensive list of references.



ROSE RESEARCH ON LYMPHADENOMA.

Contributors: Sir Thomas Horder, M. H. Gordon, Kenneth Stone, Lawrence P. Garrod, E. R. Cullinan, B. D. Pullinger. *William Wood and Co., Baltimore.* \$7.25. 10 $\frac{1}{8}$ x 7 $\frac{1}{2}$; v + 136 + 98 plate figures.

The series of papers presented in this book report the essential findings of the last four years of work of the Rose Research on Lymphadenoma. Considerably over half of the volume is devoted to Dr. M. H. Gordon's studies on the etiology of lymphadenoma or Hodgkin's disease, in which it is shown that the etiological agent is not a spirochete, the tubercle bacillus, or a mycotic organism. On the other hand highly convincing evidence is given which indicates that the true causative agent is a particulate, living micro-organism of the type of the larger viruses. Other papers in the book include Sir Thomas Horder's clinical description of Hodgkin's disease; Kenneth Stone's and

Lawrence Garrod's studies on the serological and morphological characteristics of the yeasts found in adenomatous glands; E. R. Cullinan's hematological observations of inoculated rabbits and guinea pigs; and B. D. Pullinger's contribution to the histology and histogenesis of the lymphoid tissues. Altogether the book is representative of the highest type of cooperative research. The cytological drawings are examples of both superlative medical art and excellent printing.



THE DISTRIBUTION OF THE CURRENTS OF ACTION AND OF INJURY DISPLAYED BY HEART MUSCLE AND OTHER EXCITABLE TISSUES. *University of Michigan Studies, Scientific Series, Volume X.*

By Frank N. Wilson, A. Garrard Macleod and Paul S. Barker. University of Michigan Press, Ann Arbor. \$1.50 net. 10 $\frac{3}{4}$ x 8; vii + 59; 1933.

Preliminary reports dealing with this investigation have been published (*Proc. Soc. Exp. Biol. Med.*, Vol. 27, p. 588, 1930, and *Jour. Gen. Physiol.*, Vol. 16, p. 423, 1933) but these papers did not include the discussion of currents produced by injured tissue and the intermediate stages of the mathematical treatment presented here. The starting point of this study is the proposition that the electrical relations of organs surrounded by air, as many physiologists have been content to study them, must differ from the relations within the body because air is a good dielectric. The purpose of this treatise is "to discuss in some detail the laws that govern the flow of electric currents in volume conductors; to apply them to the analysis of certain curves obtained with the string galvanometer by leading directly from the surface of the mammalian auricle and from the injured surface of the turtle's ventricle" and to explain the results in terms of the membrane theory.



THE MODERN TREATMENT OF SYPHILIS.

By Joseph E. Moore. Charles C. Thomas, Springfield, Ill. \$5.00 postpaid. 9 $\frac{1}{8}$ x 6 $\frac{1}{2}$; x + 535; 1933.

This volume satisfies a great need in medical literature. Written by an outstanding clinician it gives in clear and precise terms the therapeutic measures found most effective in the different types of syphilis. The general practitioner, for whom it is intended, will find its fundamental empiricism a relief from the vagueness of theoretical textbooks. While the author does not neglect the philosophical theories, and, in fact, gives an adequate exposition of them, he emphasizes particularly the practical aspects and derives his conclusions almost wholly from his long experience at the head of one of the largest clinics in the country. The statistics presented to justify these conclusions are impressive, but, in our opinion, would carry greater conviction if the data comprised a larger sample of the vast material collected.

In the human biologist especial interest is aroused by the author's comments on the social and personal aspects of the disease, which really deserve further amplification and should be brought to the attention of the layman.



TRAITÉ DE PHYSIOLOGIE NORMALE ET PATHOLOGIQUE. Tome I. *Physiologie Générale.*

By L. Ambaré, M. Arthus, É. Bachrach, A. Blanchetière, H. Cardot, A. Chevallier, A. Lacassagne, A. Policard, G.-H. Roger, J. Verne, F. Vlés. Published under the direction of G.-H. Roger and Léon Binet. Masson et Cie, Paris. 165 francs. 9 $\frac{5}{8}$ x 6 $\frac{5}{8}$; xvi + 1140; 1933.

It is not likely that this introduction to general physiology will fulfill the expectation of its editor and "enhance the prestige of French science." The collaborators in this enterprise have written with considerable literary skill of the general status of their several fields of knowledge and have pointed out certain unsolved problems but they are rather hazy about just what has actually been found out, particularly when the work has been done outside of France. The best section is a survey of biochemistry by Blanchetière which takes up about half the book, and is the only section accom-

panied by an adequate bibliography. Besides this, there are general surveys of chemical physiology and physical chemistry, and a number of chapters that seem to have been included because they did not belong in any other of the eleven volumes of this treatise. There is no index.



BEHIND THE DOCTOR.

By Logan Clendenning. Alfred A. Knopf, New York. \$3.75 net. 9 $\frac{1}{4}$ x 6 $\frac{1}{8}$; xxxii + 458; 1933.

This *histoire romancée* of medicine is excellent and, within its limits, very accurate. The scrupulosity of the author is such that he has added an appendix to indicate the points where he has given free play to his imagination or where the authenticity of the historical source is doubtful. The author's intention is to give the layman an understanding of the discoveries which have contributed to the present state of medical knowledge and practice. To accomplish this in an entertaining manner he considers these discoveries in terms of the individuals whose investigations have directly or indirectly led to them. With rare literary skill he describes their personalities, physical and spiritual, their environments, and the means by which they achieved their goals.

Of the many recent popular books on medical history this is without a doubt one of the best.



LA DUALISME DE LA CONTRACTION CARDIAQUE. *Recherches Expérimentales du Laboratoire de Thérapeutique de l'Université de Liège.*

By F. Henrijean. Masson et Cie, Paris. 50 francs. 9 $\frac{3}{4}$ x 6 $\frac{1}{4}$; xi + 350; 1933 (paper).

In this posthumous publication of the eminent Belgian physiologist are recorded the ultimate theories derived from his investigations on the nature of the heart beat. Special emphasis is placed on the fact that in certain conditions spontaneous

contractions and formation of the rhythmical electrical phenomena of the heart persist after death. Also, experiments on the effects of chloroform, ether, and variations in the quantity of the sodium, calcium, or potassium ions on the cardiac functions as observed with electrocardiograms lead the author to reject the possibility that the myogenic or neurogenic theories alone can explain the character of the cardiac contraction. The complicated picture which he presents cannot be here described but in the reviewer's opinion warrants further investigation.



LES RÉACTIONS DU TISSU PULMONAIRE DANS LA TUBERCULOSE. *Étude Expérimentale et Interprétation. (Substratum Anatomo-Pathologique de l'État d'Allergie).*

By E. Leuret and J. Caussimon. Masson et Cie, Paris. 30 francs. $9\frac{1}{4} \times 6\frac{3}{4}$; iv + 85; 1933 (paper).

This is one of a series of studies on tuberculosis undertaken under the direction of Professor Léon Bernard. Experimental work on rabbits leads the authors to the view that in pulmonary lesions the important factor relative to the outcome is the reaction of the tissues to the causative foreign elements. The elimination of these elements they observe follows a simple scheme. This is evidently not so in human tuberculosis. They explain this departure from the simplicity of reaction on the basis that the follicular lesions are caused by more or less temporary fixation of tubercle bacilli, so that, in the evolution of the disease there is formation of polymorphic lesions due to alternating fixation and elimination.



THE NEW DENTISTRY. *A Phase of Preventive Medicine. Six Lowell Lectures.*

By Leroy M. S. Miner. Harvard University Press, Cambridge. \$2.00. $7\frac{1}{2} \times 4\frac{7}{8}$; 219; 1933.

The development of dentistry as a modern science is outlined in an interesting and readable form. Archeological evidence of

dentistry is reviewed; the crude as well as clever craftsmanship of historical ages is pointed out; and the discussion of the replacement of mechanical dental procedure by a broad knowledge derived from biological research makes up the major part of the book. Although the style is that of the popular lecture, the thoroughly scientific outlook of the author is always evident. The book can be recommended as a worthy appeal for unbiased programs of research in all phases of biology.



LES PRÉMATURÉS. I. *Physiologie du Pré-maturé*, by H. Vignes. II. *Étude Clinique et Thérapeutique*, by G. Blechmann.

Masson et Cie, Paris. 20 francs. $7\frac{3}{4} \times 5\frac{3}{8}$; 166; 1933 (paper).

The physiological inferiority of the premature infant is described by Dr. H. Vignes in the first part of this book. He observes that the probability of survival is dependent upon the degree of prematurity, the absence of birth trauma, and the absence of congenital disease. In the second part, Dr. Blechmann discusses the clinical measures and therapy that aid a normal adaptation to extra-uterine life. It is written in concise style and the review of the literature is excellent.



PROBLÈMES THÉORIQUES ET PRATIQUES DE LA TRANSFUSION SANGUINE. *Dix Leçons: Indications. Groupes Sanguins. Accidents. Technique. Organisation. Hémothérapie. Phylactotransfusion. Immunotransfusion.*

By Arnault Tzanck. Masson et Cie, Paris. 35 francs. $9\frac{1}{8} \times 6\frac{1}{8}$; 212; 1933 (paper).

The author appears to have covered pretty thoroughly in this handbook the work of the French on blood transfusion. The material is divided into ten sections covering the ground indicated in the title. It includes a discussion of transfusion from cadaver to living man, and ends with 28 aphorisms. The bibliography of three pages is confined to French items, mostly by the author and his co-workers in the hospitals of Paris.

OUR COMMON ENEMY: COLDS.

By the Editors of "Fortune" in Consultation with Eminent Physicians. Robert M. McBride and Co., New York. \$1.00. 6 $\frac{3}{4}$ x 4 $\frac{1}{2}$; 102; 1934.

This little book sums up for the general reader what is known about the causation and treatment of colds. The good old remedy, "rest in bed," still seems to be the best measure, not only to cure a cold, but to prevent its spread to other victims. The book was published too early to mention the encouraging results found by Diehl from the use of codein and papaverin. The second part of the book gives an amusing description of the business of advertising and selling cold remedies.



DIET AND DENTAL HEALTH.

By Milton T. Hanke. University of Chicago Press, Chicago. \$4.00. 9 x 6; xi + 236; 1933.

With the financial assistance of the California Fruit Growers Exchange, the author and the Chicago Dental Research Club (an organization of twelve practicing dentists) are able to present in this book convincing evidence that in the majority of growing children gingivitis may be prevented and cured, and dental caries may be arrested and prevented, by the daily addition of one pint of orange juice to an otherwise adequate diet. The book is not well written and includes much that is superfluous; its value is greatly enhanced by the inclusion of a series of beautiful color photographs and an appendix of seriatim observations for a three-year period of the oral status of 400 children.



SYMPOSIUM ON METABOLISM. *Sigma Xi Lectures for 1933. Ohio State University.*

Ohio State Chapter Sigma Xi, Columbus. \$1.00. 10 x 6 $\frac{1}{2}$; 130; 1933 (paper).

T. M. Carpenter contributes two very readable articles, one on the history of the measurement of the gaseous products of

metabolism and heat production in man, in which the principles underlying the measurement are explained nicely; and one on the interpretation of such data. J. R. Murlin discusses the work done on carbohydrate metabolism in his laboratory; J. B. Brown reviews fat metabolism briefly; W. C. Rose discusses the nutritional significance of amino acids; E. B. Forbes has a chapter on mineral metabolism; and G. M. Curtis rounds off the collection with a paper principally devoted to the iodine-goiter problem. The whole series makes a convenient introduction to the field for anyone who has had a year or two of chemistry.

STARLING'S PRINCIPLES OF HUMAN PHYSIOLOGY. *Sixth Edition.*

Edited and Revised by C. Lovatt Evans. The Chapters on the Central Nervous System and Sense Organs Revised by H. Hartridge. Lea and Febiger, Philadelphia. \$8.75. 9 $\frac{3}{8}$ x 6; xiii + 1122; 1933.

We have already commented (Vol. I, p. 599) on the masterly way in which the whole field of physiology was surveyed by the late Professor Starling. The sixth edition, prepared by Professor Evans, has been thoroughly revised and several chapters have been largely rewritten to keep up with recent developments. In this edition a few literature references, usually to reviews, have been added to each chapter.

LABORATORY DIRECTIONS IN GENERAL PHYSIOLOGY. *Third Revised Edition.*

By E. Newton Harvey and Arthur K. Parpart. Henry Holt and Co., New York. 60 cents. 9 $\frac{3}{8}$ x 7 $\frac{1}{8}$; iii + 45; 1933 (paper)

This is the third revised edition of laboratory directions covering the topics: physical chemistry of cells, movement, circulation, and respiration. The directions are clearly worded and the apparatus requirements moderate.

TRAVAUX DU LABORATOIRE DE MICROBIOLOGIE DE LA FACULTÉ DE PHARMACIE DE NANCY. *Fascicule VI.*

Faculté de Pharmacie, Nancy. 9½ x 6½; 164; 1933 (paper).



BIOCHEMISTRY

MEDIZINISCHE KOLLOIDLEHRE. *Lieferungen 6, 7, 8 und 9.*

Edited by L. Lichtwitz, Raph. Ed. Liesegang and Karl Spiro. Theodor Steinkopff, Dresden. 5 marks each. 10½ x 7½; Lief. 6, pp. 385-464; Lief. 7, pp. 465-528; Lief. 8, pp. 529-608; Lief. 9, pp. 609-688; 1933 (paper).

Previous sections of this excellent series of papers on the application of colloid research to medicine have already been noticed in these columns. In the present four numbers K. Klinké discusses blood (with a section on thrombosis and embolism, by H. Lampert, and one on the vehicular function of the white corpuscles, by Hermann Bernhold) and lymph; R. E. Liesegang writes on water economy, the kidneys, stomach and intestines; J. Tannenbergl treats the blood-vessels; and G. Boehm contributes a paper on muscle.



HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 423.* Containing following articles: *Methoden zur Untersuchung der chemischen Zusammensetzung von Bakterien*, by Erwin Chargaff; *Bakteriologische Differentialdiagnose*, by Otfried Ehrismann.

Urban und Schwarzenberg, Berlin. 15.60 marks. 10 x 7; 334; 1933 (paper).

The first paper in this number of the *Abderhalden Handbuch* gives in 57 pages the methods of determining the chemical composition of pneumococci, Friedländer bacilli, the human, bovine and avian tubercle bacilli, hay bacilli, *Bacillus Calmette-Guérin*, and the diphtheria bacillus.

The second paper on bacteriological differential diagnosis contains instructions for identification, staining and culture.

The second paper is indexed and both are documented.



LE PHOSPHORE. *Techniques Chimiques—Physiologie—Pathologie—Thérapeutique.*

By M. Labbé and M. Fabrykant. Masson et Cie, Paris. 55 francs. 10 x 6½; 395; 1933 (paper).

This is a thorough and systematic review of the present knowledge of the chemistry and metabolism of phosphorus and its rôle, physiologically and therapeutically, in certain diseases such as those of the liver, kidneys and bone, anemia, rickets and tetanus. In the lengthy bibliographies provided for each section, French, German and English investigators are fairly evenly represented.



SEX

HUMAN SEX ANATOMY. *A Topographical Hand Atlas.*

By Robert L. Dickinson. The Williams & Wilkins Co., Baltimore. \$10.00. 11½ x 9; xiii + 145 + 175 figures; 1933.

This magnificently produced volume is a monument to its author's indefatigable diligence, his love of details, and his skill as a draftsman. It is an encyclopedic atlas of sex in all its aspects, physiological, behavioristic and psychological, as well as anatomical. It is based primarily upon Dr. Dickinson's literally enormous experience as a practicing gynecologist and secondarily upon his wide knowledge of the medical literature of sex in the human species. There are 133 pages of text, divided into nine chapters and a bibliography. These chapters have to do successively with: Purpose and methods; the bony pelvis; uterus, ovaries and tubes; the vagina; the vulva and breast; male genital anatomy; the anatomy of coitus; the anatomy and control of conception; conclusion and program. The remaining and much larger half of the book consists of some 175 plates, arranged on the same plan as the text. All of these plates have

some value; some of them are superb, better than anything hitherto existing; some we regret to say are so crowded and/or so badly arranged as to be merely confusing to the reader.

Altogether this is a remarkable book, that will for a long time be found useful as a reference work. There is a detailed index, and a fairly extensive though by no means complete bibliography. One wonders, to take a single example, at the absence of citation of a book having a similar purpose, point of view and manner of treatment, also illustrated with beautiful if not too precisely accurate quarto plates in color, which appeared over 80 years ago—the *Histoire de la génération de l'homme* by Grimaud de Caux and Martin Saint-Ange.

Dr. Dickinson is an enthusiast and a crusader, trying in his very effective way to make this world a better place to live in by increasing our knowledge about sex. His books are always interesting and stimulating. And no one realizes more clearly than he the incompleteness and deficiencies of his work. Of the present volume he says that it is "a mere sketchbook, a beginning." Some day it will doubtless be followed by a much duller but more systematically thorough treatise. In the meantime every student of the subject will be sincerely grateful to Dr. Dickinson for what he has done.



BIRTH CONTROL IN PRACTICE. *Analysis of Ten Thousand Case Histories of the Birth Control Clinical Research Bureau.*

Text and Tables by Marie E. Kopp. Prepared under the Supervision of a Scientific Advisory Committee. Robert M. McBride and Co., New York. \$3.75 net. 8½ x 5½; 290; 1934.

Ten thousand cases from Margaret Sanger's Birth Control Clinic in New York City form the basis for this book. According to the preface the report was prepared under the supervision of a Scientific Advisory Committee by Marie E. Kopp. There is a vast amount of material and detail which does not always make easy

and connected reading but is clear and understandable. The book is divided into five sections dealing with sources and methods of collection, sociological and economic factors, physiological factors, indications for the postponement of conception, and a summary.

The statistical treatment is extremely simple, consisting almost entirely of percentages of this and that together with a few averages, medians, and modes. No analysis of the variation of the material in a statistical sense is attempted. There are many tables (81 in fact) given in the body of the text besides 50 master tables in small type given in the appendix. There are many interesting data presented here. Ninety-three per cent are said to have used what they believed to be contraceptives before they applied to the clinic for help. Four per cent had never been pregnant while 6 per cent had practically complete families. The latter group averaged six pregnancies apiece. Sixty per cent of the 10,000 were listed as having "general medical disorders." The results in various respects are not in accord with the data from more carefully and scientifically controlled clinics.



WOMAN'S PERIODICITY.

By Mary Chadwick. Noel Douglas, London. 6 shillings. 7¼ x 4½; 228; 1933. This book begins with a short survey of the customs, beliefs and taboos connected with menstruation and then attempts to trace

where possible the various ways in which these have been handed down to the present day, trying to show how they survive actually in curious superstitions that still obtain among civilized peoples, exercising an even more powerful influence upon their lives from recesses among the deeper structures of the mind of both men and women. From these hiding-places they may be found to originate strange ideas, dreams, phantasies, and symptoms, that assume exaggerated prominence during the menstrual period.

The content and general tone of the book follow in the main the author's earlier work *The Psychological Effects of Menstruation*, noticed with scepticism in this REVIEW (Vol. 8, p. 125).

LA DURÉE DE LA GROSSESSE ET SES ANOMALIES.

By *Henri Vigner*. Masson et Cie, Paris.
15 francs. 7½ x 5½; 97; 1933 (paper).

An elementary but comprehensive survey of the variability in the duration of pregnancy. The distinguished author is admittedly here preoccupied by the question: "Doctor, when shall I be delivered?" In this review of the many investigations on the subject he attempts to show how absurd it is to make a definite prediction. Moreover, he points out that if the facts do not bear out the prediction, the strain of expectation may have grave psychological effects on the pregnant woman. This observation is expressed with a tone of sarcasm towards the modern woman and illustrated by his own experiences with patients, for whom delay interfered with social or other amusements!



SEX HABITS. A Vital Factor in Well-Being.

By *A. Buschke and F. Jacobsohn*. Translated from the German by *Eden and Cedar Paul*. Emerson Books, New York. \$2.50.
7½ x 5½; 204; 1933.

A commendable contribution to rational sex education translated into clear and simple English. The chapters dealing with the anatomy of reproduction are well illustrated and the physiological information is thoroughly scientific. At least half of the volume is given to discussion of the social aspects of sex relative to marriage, heredity, hygiene and many other topics contributory to individual sex sanity.



BIOMETRY

OUTLINES OF BIOMETRIC ANALYSIS. Part I. Revised Edition.

By *Alan E. Treloar*. Burgess Publishing Co., Minneapolis. \$1.65. 11 x 8½; 65; 1933 (paper).

This outline was prepared for use in the author's course in Biometric Principles at the University of Minnesota. The

method of presentation was developed in large part by the late Professor J. Arthur Harris. The subjects treated are centering constants, dispersion, the normal curve, the binomial series, the χ^2 criterion, correlation and regression, and errors of random sampling. The treatment is clear and the doctrine in general sound, especially in its emphasis on statistical pitfalls. However, the standard deviation of a Poisson series is equal, not to the mean, as the author states, but to the square root of the mean.



MATHEMATICAL FACTS AND PROCESSES PRE-REQUISITE TO THE STUDY OF THE CALCULUS. Teachers College, Columbia University, Contributions to Education, No. 572. Published with the Approval of Prof. Clifford B. Upton, Sponsor.

By *William H. Fagerstrom*. Bureau of Publications, Teachers College, Columbia University, New York. \$1.50. 9 x 5½; vii + 68; 1933.

Since one of the important functions of high school mathematics is the preparation of the student for the study of calculus in his college work, the author has analyzed the problems in Granville, Smith and Longley's *Elements of the Differential and Integral Calculus* to see how much of what has been taught the student in high school is actually used in his calculus course. He concludes that part of the time spent on advanced algebra and trigonometry might better be given to analytic geometry.



PSYCHOLOGY AND BEHAVIOR

RACE PSYCHOLOGY. A Study of Racial Mental Differences.

By *Thomas R. Garth*. Whittlesey House, McGraw-Hill Book Co. \$2.50. 8 x 5½; xiv + 260; 1933.

This is a timely book. It contains much that will be useful to the student of human biology while at the same time it is well within the grasp of the general reader. The author has collected all the results

of a scientific nature on racial differences in mental traits that have been made since 1881. He also includes much of his own work. All the data are tabulated in such form as to be readily comprehended. So much work of a preliminary character remains to be done in this new field that many sections of the book are merely discussions of future lines of profitable study. Three pertinent facts are emphasized in the summary. (1) Selection operates in man as well as elsewhere. "One race of men may profit by the operation of selection, either natural or artificial, while another may not." "That is, through selection one trait may be emphasized in one and not in another, though both possess the trait in common." (2) The races of men are mobile. "What we call races are merely temporary eddies in the history of humankind in which common human traits—at least somatological traits, if not mental traits—have become emphasized. Removal of the barriers causing the eddies causes the emphasis to dissolve in the common racial stream." (3) Nurture changes native traits. "Much of the difference found in the results of studies of racial differences in mental traits is due to differences in nurtural factors and the rest is due to racial mobility, so that one race has a temporary advantage over another." The work contains a lengthy bibliography and an appendix giving a description of experimental and statistical studies in race psychology. There are author and subject indices. R. S. Woodworth contributes a foreword.



HUMAN MENTALITY *in the Light of Psychiatric Experience. An Outline of General Psychiatry.*

By Bror Gadelius. Levin und Munksgaard, Copenhagen. Dan. Cr. 33. 9 $\frac{3}{4}$ x 6 $\frac{1}{4}$; 620; 1933.

This translation of a revised and enlarged edition of parts I and II, together forming an independent volume, of a Swedish textbook is intended as a general guide to psychology as well as psychiatry. The book opens with a brief historical survey of psychiatric theories and practice and

the care of the insane, and a consideration of epistemological viewpoints. Sections follow treating the functional structure of mental life and its morbid changes, the genetic and exogenous causes of mental disease, and treatment. The author's approach is predominantly psychological, and he little more than glides over the morbid anatomy. However, he discusses at length the rôle of the endocrine glands and the vegetative nervous system in mental disorder.

Gadelius apparently has little use for Freudian doctrines and includes a chapter on psychoanalysis merely because

as I have desired to maintain the extreme importance of psychotherapy in every form of mental suffering, I have found it advisable in view of the great influence exercised by the Freudian doctrines, and the impress of dogmatic one sidedness they have imparted to the theory and practice of medical treatment, to subject psychoanalysis to a critical examination.

Although the book will scarcely be found suitable as a textbook for beginners in this country, it will be valuable to advanced students who wish to become better acquainted with the views of European psychiatrists.

Bibliographies are appended to the separate chapters. The index is not very adequate.



A SURVEY OF THE SCIENCE OF PSYCHOLOGY.

By J. R. Kantor. *The Principia Press, Bloomington, Ind.* \$3.75 postpaid. 9 x 6; xvii + 564; 1933.

Kantor takes the view that all psychological phenomena must be described as part of the activities of an entire organism engaged in preserving a balance among its own numerous processes and in responding to the influences of the environment in such a way as to preserve its totality. Accordingly, his treatment may be classified as organismic. The distinctive feature of the book is the large number of separate fields of human biology which are surveyed in order to provide a basis for a complete description of a psychological organism. There are chapters on human anatomy and physiology, brief reviews of the fundamentals of genetics and development, and in connection with the

discussion of man's ecological relationships there are two chapters on human races and the means by which they can be studied. It is written as a textbook for college students, with the numerous chapter subheadings and subdivisions usually considered appropriate, and it ought to be a good book for college students to be exposed to. In addition to explaining the principles of psychology, the way in which they have been worked out, and the nature of the problems now under study, in an interesting and frequently original way there are a good many provocative introductions to ideas on other subjects as well. For instance, "Free thinking is a rarity. Freedom of thought, in the ordinary sense of the word, merely means that we are not prevented by some particular group from thinking the way some other group does." There are 45 pages of literature references to other textbooks and to recent articles in the standard psychological journals classified according to subject matter, and an excellent index.



THE BLIND IN SCHOOL AND SOCIETY. *A Psychological Study.*

By Thomas D. Cutsforth. D. Appleton-Century Co., New York. \$2.50. 8 x 5½; xvii + 263; 1933.

Dr. Cutsforth, Instructor in Psychology in the University of Kansas, in this book tells us what is wrong with the present system of education for the blind, and gives suggestions for corrective measures. To use a simile of the author's, teachers generally liken a blind child to a six-cylinder automobile with one cylinder missing, rather than one with a five-cylinder engine "organized to function perfectly upon his level of sensory equipment." They therefore think that "his education must not only be education, but must also supply the missing power and also make the car sound as if it really were hitting on six cylinders."

Tests made on children in schools for the blind showed that more often than not the children employ visual concepts when other sensory ones are just as available and much more meaningful to them.

Like most pupils the blind are prone to give the answer expected of them by the teacher to make a passing grade. The author, of course, makes no objection to teaching the use of visual symbolism to the blind, so long as no attempt is made to discredit their own meaningful sensory experience.

The thesis that the conventional education given the blind leads to verbal, intellectual and esthetic hypocrisy, as well as to psychological and social maladjustments, is carefully argued, convincingly written and illustrated with numerous case histories. The book is a noteworthy contribution to the psychology of the blind, and should not be neglected by those concerned in their education.

A glossary, bibliography, an appendix of "problems for further study" and an index are provided.



A HUNDRED YEARS OF PSYCHOLOGY. 1833-1933.

By J. C. Flugel. The Macmillan Co., New York. \$3.75. 8½ x 5½; 384; 1933. This stimulating and well written book is the first of a series designed to trace the history of the various sciences during the past hundred years. After a survey of psychology as it existed a hundred years ago, a time when its close connection with physiology, and its possible practical applications, especially in education and the study of mental disease, were beginning to be realized, Professor Flugel divides his century into three parts, 1833-1860, 1860-1900, and 1900-1933. In the first of these periods the tendencies already noted continued to develop. The second period is characterized by the growth of experimental psychology and of the evolutionary point of view consequent on Darwin's *Origin of Species*. In the third period "we find psychology embarking on the process of specialization incidental to the growth of new schools, each school having its own peculiar methods and outlook and even to a considerable extent its own peculiar jargon." The description of the various schools and their work gives the reader a clear and vivid picture of the progress of psychology in the past

three decades. In particular, the chapter on Freud is one of the best brief expositions of psychoanalysis that we have found. Flugel emphasizes especially the sociological importance of Freud's work on the super-ego. Only by realizing the archaic and irrational character of the morality that the super-ego imposes can we hope to evolve a more reasonable and humane morality. The book contains a bibliography of ten pages, a chronological table of events in the history of modern psychology, and author and subject indexes.



THE NATURE OF HUMAN CONFLICTS, or *Emotion, Conflict and Will. An Objective Study of Disorganisation and Control of Human Behaviour.*

By A. R. Luria. Translated from the Russian and edited by W. Horsley Gantt. Liveright Publishing Corp., New York. \$4.00. 8 $\frac{1}{2}$ x 5 $\frac{1}{4}$; xvii + 431; 1932.

Here are presented the results of an experimental psychological investigation on the disorganization and control of human behavior. The ingenious method of routine investigation records, in relation to time and form, the individual motor and speech reactions to spoken stimuli. Thus, according to the author, is reflected "the whole dynamic character of the central neurodynamic process of the attention."

In the first part, on psychophysiology of the affective processes, are illustrated the abnormal reactions associated with various forms of emotion. These lead to the conclusion that "marked disturbances in the motor system occur every time the movements fall directly into the sphere of affect" and this is attributed to the fact that "the cortical apparatus is not in a condition to dominate the masses of excitation in the affect."

In the second and third parts of this volume the author seeks to determine the mode of action and genesis of the conflicting processes which cause the abnormal neurodynamic reactions. This he attempts to determine by the creation of artificial conflicts, observations on hys-

terical patients, etc., and especially in the study of the development of behavior from childhood to adult age.

This work is an outstanding contribution to psychology.



HYPNOSIS AND SUGGESTIBILITY. *An Experimental Approach.*

By Clark L. Hull. D. Appleton-Century Co., New York. \$3.75. 8 $\frac{3}{4}$ x 5 $\frac{7}{8}$; xii + 416; 1933.

The primary purpose of this treatise is to make available to the general public the results of a program of experimental research on the problems of hypnosis carried out in Professor Hull's laboratory at Yale over a period of about ten years. In doing this the author has correlated and integrated this work with that of others reported in the literature. The net result is a useful and significant presentation of the whole subject, viewed from a rigidly objective experimental standpoint. The author has no illusion about the extraordinary difficulties and complexities inherent in the phenomena of hypnosis and suggestibility. He says:

These difficulties are so great that to enter seriously on a program of investigation in this field is a little like tempting fate; it is almost to court scientific disaster. Small wonder that orthodox scientists have usually avoided the subject! Yet each generation may be expected in the future, as in the past, to produce a very few rash souls who will not only risk the dangers of making scientific errors but will also have the courage to brave the semi-superstitious fears of the general public and the uneasy suspicions of their orthodox scientific brethren. It is to them that the present work is really addressed.

The author concludes as the net general result of his study that hypnosis is merely a quantitative upward shift in susceptibility to suggestion, differing only quantitatively and not qualitatively from the normal waking state. Specifically he is of the opinion that no phenomenon can be produced in the hypnotic state that cannot in lesser degree be produced in the normal waking condition.

The book is well organized and written, abundantly and significantly illustrated, and provided with adequate bibliographies and indices.

AN EXPERIMENTAL STUDY OF FACTORS INFLUENCING CONSONANCE JUDGMENTS. *A Study from the Psychological Laboratory of Vanderbilt University. Psychological Monographs, Vol. XLV, No. 2. Whole No. 201.*

By Eugene G. Bugg. *Psychological Review Co., Princeton, N. J.* \$1.50. 9 $\frac{3}{8}$ x 6 $\frac{5}{8}$; vi + 100; 1933 (paper).

Although the problem of the consonance of musical tones has been under discussion since the days of Pythagoras there is no general agreement as to the nature of the phenomenon. Some have regarded judgments of consonance as cognitive in character while others have held them to be essentially judgments of pleasantness or unpleasantness. On the basis of his experiments the author of this monograph concludes that comparative judgments of consonance are complex phenomena, which are often influenced by the affective quality of the intervals, but that consonance and affective quality are not synonymous. When subjects were given a single criterion by which to judge the relative consonance of two intervals their judgments in repeated tests were more consistent than when they used several criteria. The gross score obtained for the Seashore Consonance Test is, the author concludes, of little value. There is a bibliography of 31 titles.



THE SUPERNORMAL. *A Critical Introduction to Psychic Science.*

By G. C. Barnard. *Rider and Co., London.* 7s. 6d. net. 8 $\frac{1}{2}$ x 5 $\frac{1}{2}$; 256 1933.

"Supernormal," according to the author, "does not imply any more than that the phenomena in question are highly unusual, and take place under conditions and through agencies of whose nature we are ignorant." This book aims to study scientifically what is known "unquestionably" of psychic science. We feel sure that the author has achieved his aim since he explains many of the supernormal events as happening along the fourth dimension—which surely is scientific! In several places and connections, we are warned that the only way to prove supernormal occurrences is by being sympathetic with the medium. Attempting to seize ectoplasm is taboo. The fourth dimension, the subconscious, ectoplasm and

other equally *natural* (?) explanations are regarded as sufficient without having recourse to spiritualism.



MODERN MAN IN SEARCH OF A SOUL.

By C. G. Jung. *Harcourt, Brace and Co., New York.* \$3.00. 8 $\frac{1}{2}$ x 5 $\frac{1}{2}$; ix + 282; 1933.

The theme that recurs again and again in this collection of essays by the distinguished Swiss psychotherapist is that, while the purely intellectual fare served up to modern man by science turns out not to be an adequate diet, the neat packages labeled spiritual food which are marketed by the churches prove to be equally deficient in vitamins. Jung is therefore disposed to turn to the mysticism of the East as a richer source of spiritual sustenance. Among other interesting essays are those in which he explains his psychological theory of types and the differences between his viewpoint and that of Freud.



SOME EXPERIMENTS IN FOUR-DIMENSIONAL VISION.

By Geoffrey Hodson and Alexander Horne. *Rider and Co., London.* 6 shillings net. 8 $\frac{1}{2}$ x 5 $\frac{1}{2}$; xxv + 117; 1933.

Mr. Hodson used his faculty of clairvoyant vision in performing five experiments of looking into and through solids, and Mr. Horne did most of the writing-up. The section on results, positive and negative, winds up with the cogent remark:

"What Mr. Hodson did see, however, has greater significance than what he failed to see—to some sceptical minds, perhaps greater significance *because* he failed to satisfy all expectations."

We cannot help wondering what Mr. Hodson would have seen on that face of a cube which was held away from him, without Mr. Horne to ask him such questions as "Can you see the number 13?"



ADOLESCENCE. *Life's Spring Cleaning Time.*

By Beverley R. Tucker. *The Stratford Co., Boston.* \$1.25. 7 $\frac{1}{8}$ x 5; vii + 121; 1933.

This little volume is arranged as a guide for parents, teachers and all those who are interested in the adolescent. Essentially a handbook, it gives the reader a comprehensive appreciation of the perturbations which beset youth at this period. No cures are prescribed for the abnormal individual but those cases requiring the attention of a psychiatrist are indicated. The author is Professor of Nervous and Mental Diseases at the Medical College of Virginia. The book has no index.



DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

THE LIMITATIONS OF SCIENCE.

By J. W. N. Sullivan. *The Viking Press, New York.* \$2.75. 8½ x 5½; v + 307; 1933.

Present day science, Mr. Sullivan concludes, being concerned only with the metrical aspects of phenomena, does not give a complete account of the universe. Biology and psychology in particular have not yet developed concepts adequate to their most important problems. Purpose and values are left out of their subject matter, although science itself is inspired by the value of the disinterested search for truth.

It is very probable, as Whitehead maintains, that the notion of particle will have to be replaced by the notion of organism. In order to avoid a break of continuity the notions of physics will have to be enriched, and this enrichment will come from biology. We can look forward to a further synthesis. The science of mind, at present in such a rudimentary state, will one day take control. In the service of the principle of continuity its concepts will be extended throughout the whole of nature. Only so will science reach the unity towards which it is aiming, and the differences between the sciences of mind and matter, in their present form, will be seen to be unreal.



LA SCIENCE FRANÇAISE DEPUIS LE XVII^e SIÈCLE.

By Maurice Caullery. *Armand Colin, Paris.* 10.50 francs. 8½ x 4½; 215; 1933 (paper). This excellent brief history of French science since the days of Descartes was orig-

inally delivered as a series of lectures at the Museum of French Art in New York. Although himself a biologist, Professor Caullery does not neglect physics and chemistry and their technical applications. The essentially positive character of the French mind, he concludes, has saved it from the tendency to construct grandiose edifices of theory upon a slender foundation of facts so characteristic of German science, but has sometimes discouraged the formation of working hypotheses that might have led to new lines of experiment. There is a bibliography of four pages and an index of names.



THE ROMANCE OF RESEARCH.

By L. V. Redman and A. V. H. Mory. *The Williams & Wilkins Co., Baltimore.* \$1.00. 7½ x 5; x + 149; 1933.

In this number of the *Century of Progress Series* two industrial research chemists trace the dependence of our modern material culture on research in physics and chemistry. In these days of technological unemployment there is a growing feeling that the changes brought about by research are in danger of wrecking our social structure. The authors, however, conclude that what is needed is not less research in the physical sciences but more research in the social sciences.



LA PHILOSOPHIE SCIENTIFIQUE. *Vues Nouvelles sur ses Buts et ses Méthodes. Actualités Scientifiques et Industrielles XLIX.*

By Hans Reichenbach. Translated from the German by Ernest Vuillemin. *Hermann et Cie, Paris.* 10 francs. 10 x 6½; 42; 1932 (paper).

This interesting book deals briefly with the effect upon philosophy of modern scientific research. Kant's conclusion that space and time are mental categories antecedent to experience goes into the discard along with final causes and vitalism. Statistical regularities replace causal connections, and this change may eventually lead to the solution of the old problem of free will.

THE QUARTERLY REVIEW of BIOLOGY



THE INFLUENCE OF CATIONS UPON BACTERIAL VIABILITY

By C.-E. A. WINSLOW

Professor of Public Health, Yale School of Medicine

THE PHENOMENA OF SALT ANTAGONISM

STUDIES conducted by numerous investigators in widely separated fields of biology have revealed an interesting series of phenomena, associated with the influence of mineral salts on vital processes. The investigations of Ringer, Loeb and others on the contractility of muscle, of Loeb, Ostwald and others on the viability of *Fundulus*, *Gammarus*, Tubularians, Medusae and other marine animals, of Loeb on the development and specific gravity of *Fundulus* eggs, of Osterhout and his colleagues on viability of algae, germination of wheat embryos, electrical resistance of *Laminaria* and plasmolysis of *Spirogyra*, are outstanding examples in this field. Loeb, Feen, Clowes and others have observed roughly analogous effects produced upon the electrical resistance, swelling, osmotic pressure and alcohol number of gelatin or of artificial soapy membranes. Loeb (1) fully reviewed the earlier history of the subject and Falk (2) has presented an exhaustive review of the literature, particularly in regard to the effects of salts upon bacteria but with reference to other forms of life as well.

The most striking result of these studies has been the demonstration that electrolytes of bivalent cations are generally much more toxic (or otherwise effective) than those of univalent cations. Furthermore, in practically all the instances cited above, bivalent and univalent cations antagonize each other, the optimum solution being as a rule one which contains about 20 parts of Na to one part of Ca.

In discussing the antagonistic influence of salts on animal tissues and on algae and higher plants, it has generally been assumed that the phenomena were related to specific individual properties of the different ions involved. Thus, Loeb (3) attributed the swelling of protein caused by dilute NaCl to the formation of an ionizable protein salt and the neutralizing influence of CaCl₂ to the production of a non-ionizable salt. Osterhout (4) similarly assumed a specific increase of permeability of plant cells to be caused by Na as such and a decrease to Ca as such.

In the field of bacteriology, the chief studies on salt antagonism have been reviewed by Winslow and Dolloff (5). These investigations have covered viability of various species of pathogenic and soil

bacteria, biochemical activity (ammonification, nitrification, nitrogen fixation) and electrical resistance. The evidence for antagonism is, on the whole, less clear in these experiments than in those conducted with algae or animal tissues. In general, however, it appears that, here also, dilute Na solutions tend to favor viability and biochemical activity while a corresponding concentration of Ca produces an opposite effect. Mixtures of a monovalent and a bivalent salt, or of two univalent salts were found to be more favorable than either one alone by Eisler, Lipman and his associates, Shearer, Brooke, and Winslow and Falk. The antagonistic effect was manifest in solutions containing from five to twenty times as much Na as Ca.

VARIATION IN SALT EFFECTS WITH VARYING CONCENTRATION OF A GIVEN SALT

That such effects of salts are by no means always specific and qualitative in nature is clearly indicated on a careful survey of the literature. In such widely separated phenomena as the viability of various marine invertebrates, the development of *Fundulus* eggs, the biochemical activity of bacteria, various reactions of gelatin and certain enzyme hydrolyses and syntheses, it appears:

- a. That solutions containing single pure salts in very low concentrations are more favorable than distilled water to biological and physico-chemical processes; while
- b. Stronger concentrations of the same salts exert a precisely opposite effect.

In the case of bacterial viability, this phenomenon has been demonstrated with special clarity.

Hotchkiss (6) studied the effect upon *Es. coli* of twenty-three different chlorides in varying concentration. In every instance she found the salt toxic at a certain concentration (varying from 2.0 M with NaCl and KCl to 0.00001 M with HgCl₂); but in

the case of fifteen of the twenty-three salts she found a lower concentration (ranging from 0.25 M with NaCl and KCl to 0.000001 M with HgCl₂) which was definitely stimulating in its effect. There was no reason to believe that a stimulating concentration could not have been found in the other eight salts if more dilutions had been employed. This work was continued by Winslow and Falk (7), Winslow and Dolloff (8) and Winslow and Haywood (9) with completely confirmatory results.

Table 1 shows comparative results obtained in four distinct series of experiments in four different culture media,—the viability of *Es. coli* being the phenomenon observed in each case. Results differ somewhat in different media as would be expected, slightly higher concentrations being required to produce a given effect in the presence of more complex organic substances. In general, however, the coincidence is fairly close except in the case of HgCl₂.

Winslow and Haywood studied the zone of stimulation in greater detail and obtained the results indicated in Fig. 1. The organism observed was the same strain of *Es. coli* used in previous experiments and the culture solution was the Dolloff synthetic medium (10). The salts were all chlorides. Bacterial numbers at the end of 48 hours are expressed in percentages of the number present in a salt-free control. The abscissa scale is a logarithmic one to make comparison of the different salts possible. It is the same in all diagrams and to emphasize the difference in quantitative effect, the abscissa corresponding to 0.001 molal concentration is indicated by a heavy line.

The general phenomenon involved,—the stimulation of bacterial growth by low concentrations of salts and its inhibition by higher concentrations,—has been re-

corded by numerous other observers. It seems clearly demonstrated that all cations (even including such highly toxic substances as HgCl_2 , Pt Cl_4 , AuCl_3 , Cd Cl_2 , CeCl_3 , PbCl_2 , CoCl_2 , and AlCl_3) are stimulating to bacterial growth in sufficiently low concentration; and that all ca-

showed that, if one compares the effect of one cation with that of another, there is a definite quantitative relationship between all points on the graph of viability at varying salt concentration. In other words, if the concentration of salt A which produces a given degree of stimulation is

TABLE I
Critical Concentrations of Various Salts as Determined by Different Investigators in Various Media

SALT	MEDIUM	OBSERVER	STIMULATING CONCENTRATION	SLIGHTLY TOXIC CONCENTRATION	HIGHLY TOXIC CONCENTRATION
			M	M	M
NaCl	Water	Winslow and Falk	0.014-0.145	0.43	0.7
	Tartrate	Winslow and Dolloff	0.025-0.300	0.40	0.6-0.7
	Pepton	Hotchkiss	0.025-0.250	0.50	2.0
KCl	Water	Holland	0.145-0.436		0.7
	Tartrate	Winslow and Dolloff	0.050-0.400	0.50	0.8
	Pepton	Winslow and Dolloff	0.250	0.75	1.0
	Pepton	Hotchkiss	0.250	0.50	2.0
CaCl_2	Water	Winslow and Falk	0.001-0.140		0.4
	Pepton	Winslow and Dolloff	0.050-0.070	0.10	0.2
	Pepton	Hotchkiss	0.050-0.250		0.5
MgCl_2	Water	Holland	0.020-0.080		0.5
	Tartrate	Winslow and Dolloff	0.003-0.070	0.10	0.2
	Pepton	Hotchkiss	0.050-0.100		0.5
BaCl_2	Asparagin	Winslow and Dolloff		0.10	0.2
	Pepton	Hotchkiss	0.050	0.10	0.2
PbCl_2	Asparagin	Winslow and Dolloff	0.0000001	0.0001	0.0005
	Pepton	Hotchkiss	0.00005		0.0005
HgCl_2	Tartrate	Winslow and Dolloff	0.00000001-0.00000005		
	Pepton	Winslow and Dolloff	0.00000001	0.00000005	0.0000005
	Pepton	Hotchkiss	0.000001	0.000005	0.00001

tions (even including such ordinarily favorable substances as NaCl and KCl) are toxic in sufficiently high concentration.

THE CONCEPT OF SPECIFIC POTENCY

These investigations in the field of bacterial physiology have opened the way to a second important generalization. Winslow and Dolloff, five years ago (11)

called x and the concentration of salt B which causes the same degree of stimulation is $10x$; and if the concentration of salt A which produces a given degree of inhibition is $5x$; then, the concentration of salt B which should cause this same degree of inhibition is $50x$.

In Fig. 2 for example the upper half of the graph shows the curve for NaCl, the

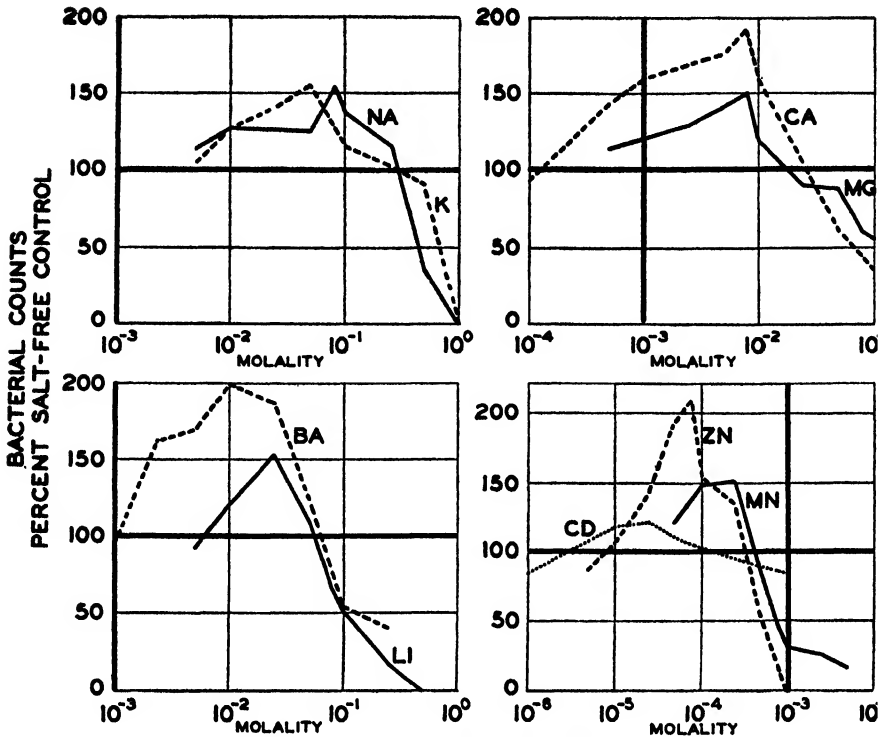


FIG. 1. RELATION BETWEEN CONCENTRATION OF VARIOUS CHLORIDES AND SURVIVAL OF BACTERIA IN A SIMPLE SYNTHETIC MEDIUM

Ordinates represent number of bacteria present expressed as percentages of the number present in salt-free control. Abscissae represent concentrations of salts on a logarithmic scale. Abscissa corresponding to 0.001 molal solution indicated by heavy line.

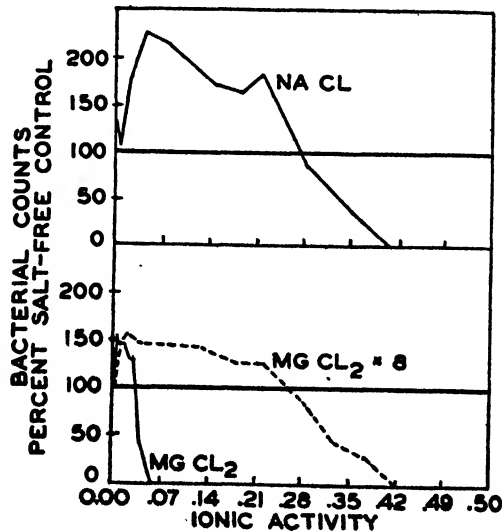


FIG. 2. VIABILITY OF BACTERIA IN CHLORIDES OF SODIUM AND MAGNESIUM OF VARYING STRENGTH

Ordinates represent number of bacteria present expressed as percentages of the number present in salt-free control. Abscissae represent computed ionic activities.

abscissae representing salt concentration in terms of ionic activity (computed from the tables of Lewis and Randall) on a direct and not a logarithmic scale, the ordinates, bacteria present after 18 to 20 hours in percentages of the number present in a salt-free control. The solid line in the lower half of the graph shows the effect of $MgCl_2$ in the same way. The dotted line in the lower section shows the

Es. coli were grown in the Dolloff synthetic medium for 48 hours at 37° . In the medium without added salt, bacterial numbers rose from 20-50 million per cubic centimeter to over 200 million per cubic centimeter. With added increments of various chlorides, the numbers rose above those for the salt-free control in dilute solutions and fell off sharply in stronger solutions. The final counts for each salt

TABLE 2

Survival of Bacteria in Salt Solutions of Various Strengths as Compared with Salt-Free Control (Per Cent)

MOLALITY	NaCl	KCl	LiCl	BaCl ₂	MgCl ₂	CaCl ₂	MnCl ₂	ZnCl ₂	CdCl ₂
1.0	0	0							
0.5	37	.91	0						
0.25	115	102	16	40					
0.1	137	115	51	54	56	36			
0.08	154		66		61				
0.05	125	155	111	123	87	62			
0.025		140	156	187	89				
0.01	127	127	121	199	119	159			
0.008					149	192			
0.005	113	104	93	170	140	176	15		
0.0025				162	128		25		
0.001				96	121	159	28	0	84
0.0008							46		
0.0005					114	142	87	57	87
0.00025							151	135	
0.0001						93	147	154	102
0.00008							137	208	104
0.00005							120	191	111
0.000025								142	121
0.00001								105	117
0.000005								85	91
0.000001									83

curve for magnesium plotted with each concentration of $MgCl_2$ multiplied by eight. It will be noted that this dotted curve closely resembles the NaCl curve above. In other words $MgCl_2$ is approximately eight times as powerful as NaCl, both in the stimulating and in the inhibiting zone.

In a later study by Winslow and Haywood (12) curves were determined in detail for nine different cations. Cultures of

solution expressed as percentages of the salt-free control are presented in Table 2. They are the same results plotted in Fig. 1 above.

From the curves thus plotted, eight arbitrary points were selected as follows: in the zone of increasing stimulation, the point where the count was 25 per cent in excess of the salt-free control and the mid-point of the zone as a whole; the point of maximum stimulation; in the zone of de-

creasing stimulation, the point showing a count 50 per cent above the control and the point showing a count 25 per cent above the control; the cross-over point where, with a rather high salt concentration, counts were again equal to those of the control; and, in the zone of toxicity, the points showing counts equal to 75 per cent and 50 per cent of the control, respectively. For each of these eight points on the curve of viability, we read off the corresponding salt concentration. The concentration of NaCl producing a given effect was taken as 1, and the concentra-

specific ionic activities were used. Nevertheless, the harmony of the results is much more striking than their irregularities; and the last column, representing an average of the eight columns to the left of it, corresponds closely with the results of other investigations. Thus, for example, the studies reported in 1928 indicated that $MgCl_2$ was eight times as powerful as NaCl or KCl. Here, the ratio is 1 for NaCl, 1.2 for KCl and 9.4 for $MgCl_2$. It seems reasonable to conclude from these results and those of other workers that all cations exert upon bacterial viability a cer-

TABLE 3
Specific Potency of Various Cations

	ZONE OF INCREASING STIMULATION	MAXIMUM	ZONE OF DECREAS- ING STIMULATION	CROSS- OVER POINT	ZONE OF TOXICITY	AVERAGE			
	Percentage of salt-free control								
	125	Midpoint		150	125	100	75	50	
Na.....	1	1	1	1	1	1	1	1	1
K.....	1	1	1.6	1.8	2.1	1.0	0.6	0.6	1.2
Li.....	0.9	1	4.0	3.0	4.3	4.7	5.1	4.4	3.4
Ba.....	9	5.0	8.0	2.3	3.4	4.7	4.5	3.4	5.0
Mg.....	4.5	5.0	10	11	17	14	5.1		9.4
Ca.....	30	17	10	9.0	8.5	9.3	9.0	6.3	12.0
Mn.....	150	170	400	300	600	700	600	600	400
Zn.....	450	250	1,000	900	600	900	900	900	700
Cd.....		1,200	4,000			2,800			3,000

tion of the other salts producing the same effect was expressed as a reciprocal of its ratio to the corresponding concentration of NaCl. Thus, for example, maximum stimulation was produced by NaCl in 0.08 M concentration and by $BaCl_2$ in 0.01 concentration. The reciprocal of this relationship is 8.

Table 3 indicates these relationships. There is considerable variation in the different columns for the same salt as would be expected from a method involving the reading of arbitrary values on a curve plotted from a few points. Furthermore, in this study molal concentrations and not

tain influence (aside from other possible influences) which is qualitatively the same. "The quantitative effect of different cations varies very widely but each has a specific efficiency, both as regards stimulation and inhibition. This characteristic, we have designated as 'specific potency.'"

The specific potencies of the cations studied by Winslow and Haywood were found to be as follows, taking the potency of Na as 1: K, 1.2; Li, 3; Ba, 5; Mg, 9; Ca, 12; Mn, 400; Zn, 700; Cd, 3000. This general order of specific potency has recently been confirmed for aerobic spore-formers by Fabian and Bryan (33).

There was some indication in the work of Winslow and Dolloff that even the hydrogen ion may fit into the same general principle, with a specific potency some 30,000 times that of Na.

QUANTITATIVE AND QUALITATIVE SALT ANTAGONISM

The demonstrated fact that each cation may exert either a stimulating or an inhibiting effect,—depending on its concentration,—must obviously be taken into consideration in studies of so-called "salt antagonism." In any mixture of salts we must, first of all, consider what results might be expected from the purely additive effect of the cations present,—with due allowance for the specific potency of each. The investigation reported by Winslow and Dolloff (13) attempted to deal with this question by studying the influence of NaCl and KCl in combination with $MgCl_2$. It showed first of all, that when $MgCl_2$ was mixed with either of the univalent salts in a proportion of 1:10 the effect of varying concentrations of the mixture was exactly what would be expected on the basis of purely additive effects. That is, if a $2x$ concentration of NaCl produced a given stimulating effect, that same effect would be produced by a mixture of x NaCl + $x/8$ $MgCl_2$,—the specific potency of $MgCl_2$ being taken as approximately 8. The curve for a mixture of KCl or NaCl and $MgCl_2$, if the actual amount of $MgCl_2$ was multiplied by 8, the actual amount of NaCl added and the sum used for an abscissa, was exactly like the curve in Fig. 2 for NaCl alone. We were dealing here with the sort of ratio (1 part of a bivalent salt to 10 parts of a univalent salt) supposed to show salt antagonism. Yet the effects are seen to be purely additive in nature.

When the total molality was kept constant at 0.5 molal concentration, but the

proportion of NaCl or KCl and $MgCl_2$ was varied, quite similar results were observed. There were certain points on the curve where a suggestion of possible specific qualitative antagonism was obtained; but, in general, the results were exactly what would be expected from a summation of the effect of each salt taken by itself.

Winslow and Haywood (14) attempted to put the specific potency theory to a crucial test by mixing NaCl in five different proportions with each of seven other chlorides and then repeating the process with $CaCl_2$, mixed in five proportions with each of six other salts. Each admixture should, on the theory of additive specific potency, have produced a count equal to that of the salt-free control (corresponding to the "cross-over point" at which the descending curve cuts the 100 per cent line in Fig. 1). With NaCl and all the salts mixed with it the results were close to expectancy. Out of thirty-five mixtures all but two showed counts between 75 and 125 per cent of the salt-free control. $CaCl_2$ mixed with either KCl, $MgCl_2$ or $MnCl_2$ gave similar results. Mixtures of $CaCl_2$ with $BaCl_2$ on the other hand yielded results higher than would be expected (118–167 per cent of the control); while $CaCl_2$ mixed with LiCl and $ZnCl_2$ gave results lower than the theory would warrant (37–65 per cent of the control).

These last observations furnish a salutary warning against any generalization which tends to oversimplify the phenomena of salt action. Yet it seems clear that the phenomenon of specific potency and the results of additive effects must be taken into account before assuming "antagonism" in the sense of a specific qualitative neutralization by one salt of the specific qualitative influence of another salt.

In interpreting the effect of salt mixtures we must also be quite clear as to the differ-

ence between mixing two salt solutions of known strength (which involves dilution of each) and the addition of solid salt to a solution of another salt (which does not involve dilution). It is obvious that if we take two different concentrations of the same salt and mix them the effect will be the same as that of an intermediate concentration. What that result will be, however, will depend on the particular part of the potency curve at which the concentrations used may lie. Thus from Fig. 1, it appears that if we mix two concentrations of NaCl, both of less than 0.05 M strength, we shall get a stimulating effect intermediate between that of the two concentrations used (since both lie in the zone of increasing stimulation). If, however, we mix a concentration lying in the zone of increasing stimulation (say 0.01 M) with a concentration in the zone of decreasing stimulation (say 0.1 M) we shall obtain a greater stimulation than that given by either primary concentration alone since the mixture will correspond to the point of maximum stimulation. If we mix a concentration lying in the zone of diminishing stimulation (say 0.1 M) with a concentration in the zone of toxicity (say 0.44 M) we shall obtain a neutralization of effects. The last two are just the sort of phenomena often described as antagonism when two salts are used. Yet with one salt alone it is clearly not antagonism but addition which is taking place. The results here discussed show that when different salts are used the phenomena often follow the same law and, when they do so, the assumption of antagonism is superfluous.

In other studies of so-called antagonism, instead of mixing two salt solutions (and thus diluting each) a second salt is added to a solution of the first salt, keeping the concentration of the first unchanged. Here the problem is simpler but the result will

still be largely determined by the part of the specific potency curve in which the addition takes place.

Thus, if we start with a salt concentration lying in the zone of increasing stimulation the addition of a small amount of another cation will push the total cation concentration up to the point of maximum stimulation. A larger addition will carry the total concentration over to the zone of decreasing stimulation or the zone of toxicity. If we start with a salt concentration giving maximum stimulation the addition of any other cation will carry the total concentration into the zone of decreasing stimulation or toxicity; so that starting at this point any salt will appear antagonistic to any other salt, even if the concentration of the second salt added were itself stimulating in effect.

The only thing that cannot occur according to the principle of specific potency is the neutralization of toxic effect by the actual addition of any cation to a solution already toxic (without dilution). This is the critical test, since according to the uncomplicated effects of specific potency, the addition of any amount of a second cation should increase the toxic effect of the first.

One of the clearest cases of such true antagonism was presented by Winslow and Falk (14) with regard to Na and Ca. Solutions of 0.6 M NaCl and 0.1 M CaCl_2 were highly toxic but a solution containing both these salts in approximately the same concentration was non-toxic. In a later paper the same authors showed that this phenomenon only occurred in alkaline solutions and was related to the influence of calcium on the power of the cell to buffer the adjacent medium, which influence was eliminated by NaCl (Winslow and Falk, 15).

Eisler (16), Lipman (17), and Brooks (18) have all reported results of this kind,

which seem to indicate true qualitative antagonism of salts in their influence on bacterial viability. On the other hand, such observations as those of Shearer (19) can readily be explained as due to additive effects.

Whatever more complex and specific qualitative effects may be superimposed thereon, it seems clear that there is a fundamental and qualitatively similar influence exerted by all cations upon the bacterial cell. This influence takes the form of stimulation of viability when the cation is present in low concentration and of inhibition when it is present in higher concentration; and each cation has a certain specific potency which determines its quantitative influence. Only when due allowance has been made for the direct additive results of the cations present operating according to their characteristic potencies, can true antagonism be postulated.

How far this same principle may apply to higher forms of life, we cannot say; but it seems highly desirable that the possibility of similar influences should be borne in mind. The results obtained by Loeb with marine animals and by Osterhout with Algae seem to offer close parallelisms with those observed in our bacteriological studies.

THE INFLUENCE OF ANIONS

It would be obviously incorrect to assume that the influence of salts upon bacterial viability is entirely due to the effect of the cations involved. In many instances, we know that the anion is important; while in other cases the undisassociated salt is specifically active.

The literature of anion effects has not been voluminous but considerable work has been done on the hydroxyl ion, much of which has been summarized in a study by Fabian and Winslow (20). This investigation was designed to be comple-

mentary to the earlier studies from this laboratory in which the effect of various cations in combination with a single anion (Cl) was observed. Here, on the other hand, Na was employed as the uniform cation. The compounds tested were NaOH, Na_2CO_3 , Na_3PO_4 , NaHCO_3 , Na_2HPO_4 , NaCl, Na_2SO_4 , NaH_2PO_4 and mixtures of the same salts with NaOH,—fifteen different solutions in all. For each solution seven to eighteen different concentrations were studied, the whole study involving the pouring of approximately 3700 plates.

All of the solutions gave us graphs generally similar to those in Figs. 1 and 2. The concentration of Na producing a stimulating effect was essentially the same whatever the anion might be (between 0.001 and 0.10 molal for 25 per cent stimulation). In the zones of decreasing stimulation and toxicity, however, NaOH, Na_2CO_3 and Na_3PO_4 with their mixtures were highly potent and approximately of the same order of magnitude while the other five substances, NaHPO_4 , NaHCO_3 , Na_2HPO_4 , NaCl and Na_2SO_4 , required from 20 to 100 times the same concentration to produce a given effect.

These results obviously suggested that hydrogen-ion concentration was the second major factor in the situation. To test this, we prepared a graph which has been redrawn in Fig. 3. In this graph, ordinates represent logs of molal concentration of sodium and abscissae represent pH values (logs corresponding inversely to molal concentration of hydrogen). In the original graph, from which Fig. 3 has been simplified, the average bacterial count (in per cent of the salt-free control) was written down at the appropriate point, for each of 158 salt mixtures studied, irrespective of the alkali or salt concerned. After this was done, as may be seen by reference to the original paper, the numbers on the chart grouped themselves in a very definite

way, the highest numbers near the upper right hand corner and the lower numbers in reasonably regular descending order as one passed outward from this area. It was possible to draw lines about each of five areas with considerable accuracy,—and these five areas are shown by cross-

three solutions showing 100–500 per cent increase, twenty-four showing 50–100 per cent increase, thirteen showing 0–50 per cent increase and three showing a decrease. Area IV included one solution showing 50–100 per cent increase, forty-two showing 0–50 per cent increase and five showing

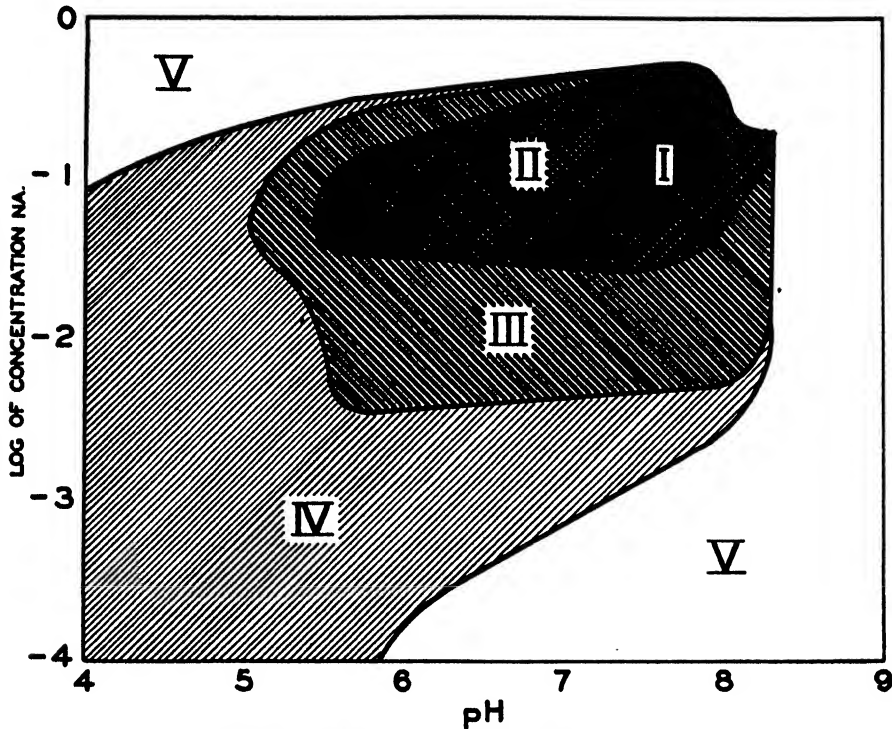


FIG. 3. GRAPH INDICATING THE SIMULTANEOUS EFFECT OF SODIUM IONS AND HYDROGEN ION CONCENTRATION UPON BACTERIAL VIABILITY, WITH 158 DIFFERENT MIXTURES OF NaOH AND OF SEVEN SODIUM SALTS

Ordinates represent total molal concentrations of sodium in these mixtures. Abscissae represent hydrogen ion concentration as pH.

The shaded areas represent bacterial viability. In Area I all counts showed an increase of 500 per cent or more as compared with the increase in the salt-free control taken as 100 per cent. In Area II most counts were between 100 and 500 per cent of the increase in the salt-free control; in Area III between 50 and 100 per cent of the increase in the salt-free control; in Area IV less than 50 per cent of the increase in the salt-free control; while in Area V nearly all observations showed a decrease in bacterial numbers instead of an increase.

hatching in Fig. 3. In Area I, there were three solutions, all exhibiting an increase of 500 per cent or more as compared with 100 per cent in the salt-free control. Area II included twelve solutions showing 100–500 per cent increase, three showing 50–100 per cent increase and two showing 0–50 per cent increase. Area III included

a decrease. Area V included five solutions showing 0–50 per cent increase and forty-two showing a decrease.

This type of diagram is of very great value since it makes it possible to observe the simultaneous influence of two more or less independent variables. Lawrence Henderson has applied a somewhat similar

principle in his studies of blood chemistry and has shown how much more significant such an analysis may be than the ordinary approach which considers but one variable at a time. Figure 3 may be interpreted in terms of a topographical map. If a layer of cardboard half an inch thick were over the whole chart, a second layer of cardboard cut to correspond to area IV, and placed on the first, a third layer cut out to correspond to area III and placed on top of the second, and so on,—we should get a relief map of a mountain with its peak in Area I, a very sharp declivity toward high pH values and high Na values and a very gentle slope toward low Na and pH values.

The correlation was not, of course, perfect and the exceptions are themselves highly significant. Of the nine solutions which showed results higher than would be expected for their sodium and hydrogen ion content, seven were phosphate solutions. Furthermore, all of the nine points in areas I and II showing an increase of over 200 per cent in bacterial count were obtained with mixtures of Na_2HPO_4 . Thus, it appears probable that the phosphate radicle exerts a specific stimulating effect. Similarly, of thirteen solutions which showed results markedly lower than would be expected, eight were carbonate solutions which may perhaps have a specific inhibitory effect.

In general, however, the main influences seem clearly to be Na concentration and hydrogen ion concentration. Maximum stimulation occurs with a sodium concentration of 0.10 M and a pH of 7.5. Decrease of Na concentration and decrease of pH value below this optimum result in a gradual diminution of stimulating effect. No doubt a further decrease of pH would have ultimately caused a sharp inhibition but we had no observations in the area of

very low Na concentration and very low pH.

An increase in Na or pH in the zones studied caused a much more rapid change from stimulation to inhibition, Na concentrations above 0.6 M and pH values above 8.3 being definitely inhibitive.

It appears clear that two major factors govern bacterial viability under the conditions of these experiments. The first is the cation concentration, the effect of all cations (according to our earlier studies) being qualitatively alike and differing in accordance with their specific potency. The second factor is the pH which, with a given cation, is determined by the anion present. The phosphate, and perhaps the carbonate, radicles exert specific influences which are superposed upon the two primary effects indicated.

THE MECHANISM OF SALT ACTION

In the studies of salt antagonism with higher plants and animal cells there has been a general indication that salts favorable to biological processes increase permeability while toxic salts decrease it. Falk (21) summarizes the evidence as follows:

In their effect upon electrical resistance [of *Laminaria*, frogskin or bacteria] bivalent cations like Ca show a characteristic tendency to cause first an increase and then a decrease in resistance, while univalent cations like Na show a uniform fall. The decrease of resistance in the two cases when it does occur, seems however to be different in nature, being irreversible in the case of the bivalent salt and reversible (if exposure has not been too prolonged) in the case of the univalent cation. The effect exerted by electrolytes appears to be primarily an effect upon external or internal membrane surfaces and upon surface interphases in colloidal systems. This is clearly demonstrated by the influence of unbalanced solutions upon the specific gravity of *Fundulus* eggs, and *Fundulus* body fluids, and upon the plasmolysis of *Spirogyra* and is strongly suggested by the changes in the electrical resistance of plant and animal tissues,

bacterial emulsions and artificial membranes. Where effects upon permeability are clearly manifest, Ca and other bivalent cations usually decrease permeability, while Na and the univalent cations always tend to increase it. We may interpret Loeb's experiments on *Fundulus* eggs as showing a decrease in permeability due to Ca; while all Osterhout's work on electrical resistance of plant and animal tissues as well as Shearer's on electrical resistance of meningococci show a preliminary decrease due to calcium followed by an increase (which is probably a wholly different phenomenon from the primary fall in resistance due to Na).

Evidence in this direction is by no means altogether harmonious. In particular, Irwin (22) in studying the effect of salts upon the penetration of dyes into the vacuole of *Nitella* found that preliminary treatment with 0.03 M NaCl decreased the subsequent penetration of dyes into the treated cells while bivalent cations had no such effect. When the salt and the dye were simultaneously present, however, 0.03 NaCl and 0.003 MgCl₂ and CaCl₂ slightly increased penetration. The latter effect is what one should expect on the theory of specific potency. In general, however, the work of Brooks (23) with dandelion tissue, of Shearer (24) and Winslow and Falk (25) with bacteria and of Osterhout (26) with *Laminaria* all tend to show that in given concentration Na increases and Ca decreases permeability; while Endler (27) demonstrated that dilute electrolytes increase and stronger electrolytes hinder diffusion in the case of green algae.

A comprehensive study of this problem has been made by Shaughnessy and Winslow (28) in order to determine the effect of various dilutions of salts upon the diffusion of certain substances outward from the bacterial cell in menstrua of varying salt content. Three types of bacterial material were studied, cells of *Es. coli* which survive in practically undiminished numbers under the conditions of the experi-

ment, heat-killed cells of the same organism and cells of *Bact. cereus* which die out almost at once in a medium lacking protective colloids. Heavy suspensions of these cells were placed in the menstrua to be tested and after exposure for selected periods up to 24 hours the cells were removed by centrifugation and tests were made for various substances in the supernatant liquor.

This study showed that marked changes take place in the menstrua surrounding either living or dead bacterial cells as a result of diffusion outward from the interior of the cells. Under conditions of normal physiological activity, these changes are of a protective nature, involving the liberation of acidic substances (CO₂) in alkaline or neutral media and of alkaline substances (NH₃) in a more acid medium in such a way as to maintain an approximate pH of 6.2-6.4. On more prolonged exposure to an unfavorable menstruum the production of ammonia overbalances that of CO₂,—a reaction characteristic of injury. Dilute solutions of NaCl (0.0145-0.145 M) tend to increase the diffusion of ammonia, carbon dioxide, chlorides and phosphates whether in the presence of living or dead cells. Stronger salt solutions (1.45 M NaCl and 0.0145-0.145 M CaCl₂) decrease the liberation of ammonia. Finally, a still stronger calcium solution (1.450 M) shows a sharp rise in titratable products in the menstruum followed by a fall. This sharp rise is attributed by the authors to a decrease in permeability so great as to lead to lysis of the cells and liberation of protein, or to a special type of membrane coagulation. The subsequent fall may be due to accumulation of non-reactive films on the protein micellae or to absorption of oppositely-charged ions.

The point in which we are here chiefly concerned is best illustrated by the results

for ammonia nitrogen cited in Table 4. It will be noted that diffusion is greatest with *Bact. cereus* (as would be expected from its great susceptibility to osmotic influences) and least in the heat-killed cells of *Es. coli*. In all instances, however, the dilute salt increased diffusion and the strong salt abolished it completely.

Since this phenomenon appeared with the cells of *Bact. cereus* (which we know die almost at once in such a menstruum (29)), and with the heat-killed cells of *Es.*

spectively, to viability. No bacterial counts were made, however, in the actual studies reported in 1927. Recently, therefore, Walker and the writer (30) repeated the experiments in a slightly different form, exposing suspensions of *Es. coli* to various salt concentrations for half an hour at 37°C. and making both initial and final bacterial counts and ammonia determinations in the menstruum after centrifuging out the cells at the end of the period. The results are presented in Table 5.

TABLE 4
Diffusion Products in Various Menstrua (pH 7.0)
Milligrams ammonia nitrogen per 50 cc.

Period of contact, hours.....	ES. COLI		HEAT-KILLED ES. COLI		BACT. CEREUS	
	0*	24	0	24	0	24
Distilled water.....	0.005	0.020	0.002	0.002	0.008	0.090
0.0145 M NaCl.....	0.007	0.034	0.003	0.012	0.009	0.150
1.450 M NaCl.....	0.000	0.000	0.000	0.000	0.000	0.000

* Centrifuged immediately after suspension.

TABLE 5
Influence of Salt Upon Viability and Diffusion Expressed as Per Cent of Results in Salt Free Control

	SALT CONCENTRATION			
	0.0	0.05-0.08 M	0.8-0.1 M	1.0 M
Final Bacterial Count.....	100	110	71	69
Rate of Ammonia Diffusion per Cell per Hour.....	100	127	84	64

coli, it seems clear that it is related not to the formation of new materials by metabolism but to some process governing diffusion from the interior to the exterior of the cell wall. Whether this process directly affects the permeability of the cell wall itself or operates through influences on the electrolyte balance inside or out, we cannot affirm with any certainty.

The conclusions from this study were fairly clear, since the salt concentrations favorable and unfavorable to diffusion were those which in other studies had been found favorable and unfavorable, re-

Again it was clear that a dilute stimulating salt concentration increased, while stronger toxic salts decreased, diffusion of metabolic products outward through the cell wall.

It seems then on the whole reasonable to associate the effects of cations upon diffusion products in the menstruum with their influence upon bacterial viability and to conclude, tentatively at least, that dilute salt solutions favor bacterial viability because they increase diffusion processes through the cell wall; and that stronger salt solutions are inhibitive because they

decrease such diffusion processes. Thatcher (34) has classed Na, K, Ca and Mg as "translocation regulators" governing the permeability of the cell. It would seem that other cations subserve the same function.

A recent study by Winslow, Walker and Sutermeister (31) has thrown a little further light on the mechanism of the stimulating process. Most of the work on bacterial viability hitherto discussed has been done by comparing bacterial counts in various salt solutions and in a salt-free control after a definite period of time. Our more recent studies have been conducted by making counts at frequent intervals in a medium continuously aerated with CO₂-free air. When the whole course of the growth cycle is thus followed it appears that both a favorable salt solution (0.1 M NaCl) and a mildly toxic solution (0.5 M NaCl) cause a decrease of bacterial numbers during the lag period of adjustment to a new medium and both show an accelerating effect in the subsequent phase of logarithmic increase. The 0.5 M concentration causes a greater preliminary decrease and a more rapid later increase than the 0.1 M concentration. That the final count reached with 0.5 M concentration is lower than that of the salt-free control is due to the fact that even this rapid logarithmic increase does not balance the earlier decrease. This is the result we might expect if both these concentrations increased diffusion, since a high degree of diffusion, under the conditions of this experiment, would be expected to be unfavorable during the period of initial adjustment (when CO₂ is deficient in the aerated medium) and favorable at a later stage.

CONCLUSIONS

In general, then, it appears that the major effects of salts upon bacterial viability may be explained on the assumption that

all cations in low concentration tend to stimulate growth and development while all cations in stronger concentration tend to inhibit growth and ultimately to exert a toxic action. The favorable effect of low concentrations appears to be associated with increased diffusion through the cell wall, the inhibitive action with decreased diffusion.

Individual cations differ very widely in their quantitative influence but, in general, the ratio between the amount of two cations needed to produce any given effect on viability is approximately the same as that between the amount of those same cations required to produce any other given effect. Sodium and potassium are, in general, the least powerful of all cations and the specific potency of other cations may be expressed in terms of the ratio between the molal concentration of sodium necessary to produce a given effect and the concentration of the other cations necessary to produce the same effect. The relative order of the cations with respect to specific potency closely duplicates their position in the E. M. F. series.

The values for specific potency computed in this way range up to 100,000 for such cations as mercury. This wide range in potency does not find its counterpart in any of the more familiar physico-chemical constants of the elements. It is, however, of the same order of magnitude as the effects recorded by Bancroft (32). According to Bancroft's theory, disinfection (like narcosis in the higher forms of life) is due to coagulation of cell colloids, the decreasing stability of these colloids in the initial stages of coagulation being associated with stimulation.

The major effect of anions upon the viability of bacteria appears to be exerted through their influence on hydrogen ion concentration.

Finally, it is by no means contended that

the specific potency of cations and hydrogen ion concentration account for all phenomena of salt action. Studies made in our laboratory have clearly shown that certain electrolytes do exert specific effects which are superposed upon the primary influences of specific potency and hydrogen

ion concentration. It seems clear, however, that in studies of bacterial viability, perhaps of other biological phenomena, the possibility of specific potency effects should be taken into account before assuming the existence of salt antagonism or other qualitative salt effects.

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FISHERY BIOLOGY ITS SCOPE, DEVELOPMENT, AND APPLICATIONS

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FOR a solid sultry week in September, 1908, three hundred official delegates to the Fourth International Fishery Congress which assembled in Washington, D.C., were engaged in the presentation of addresses and technical papers, were taking part in heated discussions and arguments, were dozing through the warm afternoon sessions, or were sightseeing after the usual manner of delegates at such conventions. Fifteen nations were represented, forty-two State Governments and territories, and a dozen learned societies and Government departments sent delegates.

The proceedings, together with the technical papers on a variety of subjects relating to the fisheries of the world, occupy 1400 royal octavo pages in the *Bulletin of the Bureau of Fisheries* for that year. The topics considered ranged from international regulation of the fisheries on the high seas, and the economic and technical conditions of the fisheries in various countries, to plans for promoting fish production in various areas, the life history and habits of aquatic animals, and a litter of papers on the artificial propagation of marine and fresh water fishes and invertebrates. Of course, the inevitable resolutions now having historic interest only were spread upon the record. The contents of the two volume report may be regarded as a fair cross section of intelligent thought upon fishery problems of the time.

Although no meeting of similar scope

or aims has been held since that day to provide a record that would show by comparison the progress the world has made in the management of its fishery resources, it is becoming apparent that new concepts of the various branches of fishery science are emerging and are becoming current. At that time fishery technology was an academic term; aquiculture was undefined, and fishery biology, if used at all, had a vastly different content of meaning and implication than it possesses today. Even among men of science these terms are now too often confused, and it is the purpose of this paper to aid in clarifying our concepts of that important field of scientific endeavor variously known as fishery science, or more properly fishery biology.

SCOPE

Possibly fishery science should be interpreted as including all sorts of systematized knowledge regarding the fisheries. Certainly, the biology of the fish upon which the fishery industry depends should be included in this broader definition. Possibly the chemistry and physics of preparation or processing of the fishery harvest for market could properly be included, and even the economics of the fish business, if organized knowledge on this subject exist, could be rated a branch of fishery science; but for practical purposes fishery biology must be much more closely defined. Probably not a few will disagree with me if I limit fishery biology to a relatively narrow field in biological

science, but, on the other hand, many of the views presented below are shared by a growing number of investigators who are becoming class conscious as fishery biologists.

One way of defining our subject is by exclusion. Fishery biology is not ichthyology; it is not statistics of fishery yields, neither is it fish culture, nor fish farming, nor even aquiculture, for the latter may be regarded as a distinct and independent branch of applied science relating to the cultivation of aquatic organisms commensurate in importance with fishery biology. Fishery biology is not identified with stream surveys or the planning of stocking programs. It is neither morphology nor the embryology of fishes. Even the study of the life history or the habits of fishes is distinct from the study of fishery biology and, of course, oceanic biology and limnology are distinct lines of endeavor.

DEFINITION

From this it may appear that there is little left if it be biology at all, but, on the contrary, fishery biology relates to all these, includes elements of many of them, and borrows the technique of others. If a formal definition is necessary, I may offer the following: Fishery biology is that body of organized knowledge regarding the natural supply of fishes commercially exploited, the variations in supply and their causes, and the ways and means of husbanding the fishery resources. It is concerned directly with the commercial fisheries.

I dwell upon the subject of defining the field of our discussion because the aim and purpose of the fishery biologist, his very point of view with regard to his science, is unique and not generally appreciated. Fishery biology must come to be recognized as an independent science, separate from any I have mentioned above, with

its own aims and technique. Its relation to zoology is similar to the relation of the various scientific branches of agriculture to botany. Zoology and botany deal with the fundamental biological principles; fishery science and agriculture have certain immediate aims differing widely from those of the parent disciplines, and their techniques must differ in a corresponding degree. Within zoology, the relation of fishery biology is more intimate with ecology, as Russell (1932) has pointed out, and with group biology as developed in population studies and vital statistics than with the classical zoology of individuals—embryology, anatomy, physiology, and taxonomy. Furthermore, in spite of the shock it gives to the conservative zoologist, its relations with economics are very intimate and important.

AIMS AND POINT OF VIEW

Since fishery biology deals with the supplies of fishes and their variations in abundance, the point of view must necessarily be quantitative, for changes in abundance imply measures of magnitude in relation to time. The census of human populations is accomplished by a physical enumeration of the individuals, with which is combined a variety of other facts regarding the characteristics of the individuals that compose the population, but practical difficulties, in the case of the sea fishes at least, make this method entirely impossible for the fishery biologist. Hence, the methods of representative statistics must be employed. A sample of the fish stock is selected with sufficient care to assure its being truly representative of the entire population from which it is drawn. This sample is then studied in detail, and from the characteristics of the sample, the characteristics of the whole may be inferred. A measurement of the accuracy of these inferences involves the theory of

probabilities and all the laws and principles of modern statistical research become at once an important part of the technique of fishery investigations. Someone has said that the maturity of a science may be gauged by the degree to which quantitative observations are employed. Fishery science has passed from the descriptive to the quantitative phase and thus may be rated a mature, if youthful, science.

I have mentioned the practical aims of fishery biology that make it comparable to the science of agriculture. It is therefore an applied science, usually accepted as the antithesis of pure science (but surely the reverse of "pure science" would be "impure science" with which I am unacquainted). Moreover, the final part of my definition, the study of ways and means of effectively husbanding the fishery resources, implies the direction of research activity to the most practical objectives. Fishery biology, therefore, is concerned with useful aquatic animals and the fisheries which they support, and every investigation dealing with other than economic forms falls in some other field of hydrobiology unless it possesses a real and definite relation to the animals that supply man's economic wants.

I do not mean to imply by this that only cod, mackerel, crabs, and the like, should be investigated. I do not intend to exclude a great array of researches upon the natural economy of the ocean or of our inland waters regardless of their complicated techniques and intricate relationships or their circumscribed objectives, so long as each specific project is designed to fill a definite place in our jig saw puzzle of a complete understanding of fish populations. The literature of fishery biology (Allen, 1926) is full of titles representing studies on carefully defined problems, many of which never mention fish, but

because of their aim, their intention, their very point of view, fit readily into our growing mosaic picture of the biological background of *fish-as-food*.

The student of biology is doubtless already aware of the existence of a rich and specialized literature on fishery biology in Europe, emanating from the various government departments, the scientific societies, and the biological stations, all of which is well reviewed in various scientific journals and adequately covered by bibliographical services. For the purpose of making more concrete the preceding discussion defining fishery biology and its aims, I may offer a few illustrations of recent research in America which may be regarded as "Simon pure" examples of fishery biology.

No formal treatise has yet been published on the scientific results of a seven year investigation of the biology of the mackerel in western North Atlantic waters, but Fishery Circulars of a popular nature have been published by the U. S. Bureau of Fisheries for the purpose of affording prompt information to the fishing industry. The first of these, "Outlook for the mackerel fishery, 1931" by O. E. Sette (1931), and succeeding circulars under the same title for 1932, 1933, and 1934 not only embody the essential concepts of modern fishery biology, but emphasize the intimate relation between this field of work and economics. The first paper cited reviews briefly the 130 year history of the North Atlantic mackerel fishery in American waters, marked by fluctuations in yield from four million pounds to 120 million pounds annually, mentions the possible causes of these fluctuations and deals at some length with the fact that the immediate cause of such tremendous changes in yield is year-class dominance; that is, the outstanding success of reproduction giving rise to great broods of young in some

years and the virtual failure of reproduction in others. It reviews the size and age composition of the stock of mackerel on which the fishery draws, estimates the mortality from all causes of the various age classes in the stock, and, on the basis of this analysis, forecasts the probable abundance of these same year classes in the following season and the estimated yield for the commercial fishery. In the succeeding papers of the series the same type of analysis and prediction is continued with additional refinements of method based on accumulating experience.

As an example of fishery biology that may well be emulated and as an achievement in research that will rank high in the annals of natural science, the work of the International Fisheries Commission, United States and Canada, under the direction of Dr. William F. Thompson, should be cited. This Commission, appointed under the terms of the convention of 1924 and that of 1930 between the United States and Great Britain for the preservation of the halibut fishery of the North Pacific Ocean, including Bering Sea, has published eight technical reports on its researches since 1930. Its scientific staff has studied where and how the halibut live, the ways in which they are fished, and the effect of this fishing upon the fish supply. Its biological studies have shown the existence of distinct stocks of halibut that inhabit different banks, grow at different rates, and possess different physical characteristics. It has followed from year to year for each stock the intensity of the fishery and the yield therefrom, showing that dangerous depletion had gone unchecked until 1930. From such studies the Commission is in a position to determine in advance the effect of any given intensity of fishing and to devise and enforce regulations of the industry that have already stayed the decline and, indeed, tended to increase the stock.

According to the authors of the eighth report (Thompson and Bell, 1934), "The conclusions from the investigations of the Commission are most striking and of profound importance to the regulation not only of the halibut fishery but, it hopes, also to many other fisheries. They indicate that in each stock the major changes are due to the fishery itself. They show, as might be expected from the history of many other fisheries, that the more intense the fishery the fewer fish survive to a spawning size. They also show that an intense fishery takes the available fish while they are still small, and that a lessened intensity allows them to grow to a larger size, but takes them just the same. Consequently, the ultimate yield obtained by the less as compared to the more intense fishery, from what young do come into the commercial catch, depends upon whether the growth in bulk exceeds or is less than the loss by natural death during the additional period they are allowed to live. Accordingly, where growth is rapid and the weight of living fish increases with time, the great intensity of the fishery is sheer economic waste in that it does not increase the total catch, but actually decreases it, as well as prevents the growth of fish to spawning size. It does not increase the yield, but lessens it, and destroys the supply of spawners. The application to regulation is obvious."

One other recent outstanding contribution to fishery biology in the United States may be cited in "Life History of the Lake Herring (*Leucichthys artedii* Le Sueur) of Lake Huron as revealed by its Scales, with a Critique of the Scale Method," by John Van Oosten (1929). In this paper Dr. Van Oosten makes a searching inquiry into the validity of the chief method of age determination in fishes, the scale method, and has firmly established its soundness for fishes in general and in particular for the species with which he was

concerned. He then takes up a study of the life history of the lake herring, analyzing representative samples of the population in Saginaw Bay, giving special attention to the age composition of the stock and the rates of growth as affected by commercial fishing operations and other artificial factors in environment, such as pollution of the water. The results in his study of the lake herring in Saginaw Bay plainly indicate a tremendously high mortality resulting from an intensive fishery and remarkable changes in the rate of growth, resulting from chemical pollution during the years 1915-1918.

As an illustration of fishery biology that includes animals other than fish, I may mention "The Relative Growth and Mortality of the Pacific Razor Clam (*Siliqua patula* Dixon) and Their Bearing on the Commercial Fishery," by F. W. Weymouth and H. C. McMillin (1931). After a sufficient analysis of the genus *Siliqua* to establish the fact that the animal under investigation is represented by a single species, *S. patula*, a careful statistical analysis of variability, sexual differences, mortality, and age and growth is made that establishes the growth norms and life expectancy of the populations of this species in different localities throughout its range from Alaska to California. Incidentally, a mathematical expression of the characteristics of growth is derived that may have universal application to all invertebrates and, indeed, to the vertebrates as well. The authors conclude that, with knowledge of the rate of growth, the length of life, and the abundance of young individuals in the different latitudes now available, they can predict the resistance of various clam beds to commercial fishing. Hence, by following a regular system of periodic censuses this valuable resource on the Pacific Coast can be regulated by legal means and permanently protected.

A few other papers may be mentioned. One series in particular bears definite relation one to the other that is not always readily discernible in other similar series: "Fishes of the Gulf of Maine," by Bigelow and Welsh (1925); "Plankton of the Offshore Waters of the Gulf of Maine," by Bigelow (1926); "Physical Oceanography of the Gulf of Maine," by Bigelow (1927); "Seasonal Distribution of Plankton of Woods Hole Region," by Fish (1925); "Production and Distribution of Cod Eggs in Massachusetts Bay in 1924-1925," by Fish (1928); "Statistics of the Catch of Cod off the Eastern Coast of North America to 1926," by Sette (1928); "Fishing Grounds of the Gulf of Maine," by Rich (1930); and "Statistics of the Haddock Fishery in North American Waters," by Needler (1931).

HISTORICAL DEVELOPMENT AND ORGANIZATION

Now that we have sufficiently defined the field of fishery biology a brief review of the historical development of this science will be comparatively easy, for by our definition we have eliminated at a stroke most of the biological research from Aristotle to Agassiz. The publication in 1914 of the noteworthy paper "Fluctuations in the Great Fisheries of Northern Europe," by Johan Hjort (1914), head of the Norwegian Fishery Department, in the *Reports of the International Council for the Exploration of the Sea* may be likened to the ceremonial laying of the corner stone in the edifice of modern fishery biology, and in 1926 Hjort added a few dabs of mortar and gave a little polishing off to the job by publishing his paper, "Fluctuations in the Year Classes of Important Food Fishes" (1926). Although the founding of a science can not be credited to any one man, Hjort probably did more than any other in defining and

giving concrete form to the concept of "vital statistics" applied to fish populations as the central theme of fishery biology. The exploration of the inter-relations of his three major variables affecting the fish supply, "birth rate, death rate, and migrations" and his demonstration of "dominance of year-classes" as causing fluctuations in abundance have had profound effect upon the development of the science and its successful application to practical problems of the fisheries. Of course, as in the construction of a building, work on the foundation and fabrication of the parts had been proceeding for a long time, carried on by many workmen in many places before the bunting was put up and the high-hat notables arrived for the ceremony of cornerstone laying; so with fishery biology foundational studies had been proceeding for perhaps a century before the incident mentioned occurred.

A systematic study of the sea started in earnest about 100 years ago and was carried out at first in connection with the work of survey and exploration undertaken by the naval ships, particularly of Great Britain and of this country. At about the same time zoologists began to extend their interests from the shallow waters to the deep sea by means of the dredge. About 75 years ago the tow-net was introduced as a means of research. Fifty years ago the great *Challenger* expedition was at sea and these researches were followed by the explorations of our own "Albatross," of the German "Meteor," the Danish, "Dana" and the British, "Discovery" (Murray and Hjort, 1912).

During the second half of the last century investigations of the sea fisheries developed gradually in the Scandinavian countries, in Germany, and in Great Britain. In 1871, the U. S. Fish Commission was established to be designated

after 1903 as the U. S. Bureau of Fisheries. In the eighties the Fishery Board for Scotland began its notable career and not long afterwards the Marine Biological Association of the United Kingdom began to concern itself with fishery problems on behalf of the British Government. At the beginning of the present century, an important step was taken in the formation of the International Council for the Exploration of the Sea. Its functions were divided between the traditional scientific investigation of the sea in all its aspects, especially the waters bordering northern Europe, and the more modern investigation of the practical problems of the sea fisheries, especially the problems of "over-fishing" and "fluctuations."

In America various temporary commissions between the United States and Canada have considered the welfare of international fisheries since 1897 and many of the investigations of the Biological Board of Canada were concerned with fishery problems as early as 1901. In 1921 the North American Council on Fishery Investigations was established and has since been functioning in coördinating researches on the fisheries in the western North Atlantic, and an international convention between the United States and Canada establishing a permanent fisheries commission, ratified in 1924 and since renewed, provides for thorough scientific investigation and regulation of the North Pacific halibut fishery.

Thus it may be seen that governments and government supported institutions are the chief agencies for the conduct of fishery investigations. Universities or other private institutions lacking resources and authority for the collection of the basic data seldom undertake direct attacks upon fishery problems, but pursue collateral or fundamental studies.

MAJOR PROBLEMS AND THEIR APPLICATIONS

Doubtless the most significant and fundamental problems of the fisheries are the understanding of the forces and mechanism of "natural" equilibrium and the maintenance of "artificial" equilibrium in fish populations. These major objectives lead at once to (1) the detection of overfishing, (2) the tracing or foretelling of fluctuations in abundance, and (3) the devising of a rational system of managing the supply for the economic advantage of man.

Although many people still believe implicitly in the inexhaustibility of the resources of the sea, in which views they are upheld by contemplation of the vast areas of waters, the tremendous fecundity of aquatic animals, and the antiquity of the great sea fisheries (see McIntosh, 1921), the fear of depletion of the more valuable species by commercial fishing has been the foundation of all governmental activity in connection with fishery investigations. That these fears were not ill-founded is amply proved by experience and, in a few cases, by sound scientific investigation. We need only look back over the statistical records of such fisheries as the Atlantic salmon and halibut, the shad and alewife in the coastal rivers of the Middle Atlantic States and in New England, and the sturgeon in these rivers and in the Great Lakes to be convinced that disaster can overtake such fisheries as the inevitable result of intensive or destructive fishing, which in some cases is coupled with the pollution of waters or obstruction of spawning beds (Van Hise and Havemeyer, 1930).

But these, you may argue, are littoral or anadromous fishes. Surely the hordes of fishes that roam the high seas are too extensive to be affected by man's puny influence. It is true that coastal and an-

adromous fishes being within easy reach of the fishermen's nets or, because of their peculiar life history, actually assembling in mass and coming to the fishermen's very door to be caught are more vulnerable than the pelagic forms. On the other hand even deep sea fisheries are subject to serious reduction as is evidenced by the fate of the Pacific halibut and by the history of the plaice fisheries of the North Sea.

In the first report of the International Fishery Commission, United States and Canada, W. F. Thompson reported that under the stress of great intensification of fishing effort on the halibut banks from Oregon to the Alaskan peninsula the abundance of fish on the grounds exploited for the longest period had fallen enormously—to 16 per cent of the abundance in earlier years. In 1906, the catch per set of the unit of fishing gear was nearly 300 pounds; in 1926, it was below 50 pounds. Accompanying this fall in abundance there was a decrease in the average size of the fish landed and a great increase in the percentage of undersized fish, all of which indicate the extensive progress of depletion (Babcock, 1931).

It is true that the herring of northern Europe which has supported a great commercial fishery for 1,000 years is still virtually unaffected, the cod in Europe likewise appears to be extremely resistant to fishing, and in the western North Atlantic has produced with only minor variations an average yield of over 100 million pounds annually for half a century. Such species seem to be especially resistant to overfishing.

OVER FISHING

Depletion in the commercial fishery is usually understood as a decline in yield per unit of effort, but a reduced level of supply in any species may be the result of a vast complex of natural causes and not

solely due to overfishing, for great variations in abundance have been observed in nature which are in no way related to depletion.

In the popular mind depletion is too often associated with the record of a declining yield in the market supply. This, however, may not be the case, for the gross figures of landings are affected by too many extraneous influences to serve as more than the merest indication of the true abundance of a species exploited. Thus economic conditions such as a brisk demand and high prices will send more fishermen to sea with more numerous and more efficient nets with the result that even with a constant or a declining supply, total yield will rise, and in a corresponding manner a decreased demand will reduce the yield regardless of the real abundance of the fishes. Hence, the study of overfishing and resulting depletion demands first of all an exact and reliable index of abundance that is uninfluenced by economic forces but measures the population remaining in the sea (Thompson, 1928).

Of course, no attempt is made to determine the absolute number of fishes in any given area, but it is of utmost importance to devise a measure of relative abundance what will be sufficiently accurate to prove whether the stock is increasing or decreasing. For this purpose the yield per hundred hours of trawling with the standard otter trawl has been employed in the North Sea for many years and has yielded valuable results (Russell, 1931). An attempt has been made to derive a measure of abundance from the yield per day's absence from port of the steam trawlers in the North Atlantic offshore banks fishery, but this measure is subject to so many errors that it can scarcely be regarded as suitable. It is, unfortunately, the only measure of abundance that can be applied to the statistics of landings that have been

collected in the North Atlantic ports by the Bureau of Fisheries for many years, although more precise records of the actual time spent in fishing are now being collected for a study of abundance of the haddock and mackerel.

The State of California has an admirable statistical system for determining yield per unit of effort from which the yield per vessel per day in the various areas can be determined with great accuracy for tuna, the offshore salmon fishery, and some others. The method of collection and utilization of such records is well described in the paper by Craig (1930).

Overfishing, however, may not be judged alone by an absolute decline in the numerical strength of the fish population in any area, for biological criteria of depletion exist that must be taken into account. It is self-evident that in any intensive fishery in which the strain falls upon mature individuals the relative proportion between the adults and the immature will be materially changed, the adults become less numerous, and the average age of the entire stock decreases. Hence, a decline in the relative numbers of adults combined with a falling yield per unit of effort indicating a decline of abundance, may be interpreted as the beginning of depletion from overfishing, while the occurrence of either phenomenon independently may indicate only natural fluctuations due to variation in reproductive success or a reduced level of abundance from other natural causes.

An analysis of the changing age composition of the fish stock is, of course, dependent upon exact methods of age determination. Probably the first successful method of age determination was that employed by the eminent Danish biologist, C. G. J. Peterson (1892), who published an account of investigations in which the age classes of fish were identified by the tabulation of

their sizes. The frequency of these sizes when plotted graphically showed modes or waves of maximum frequencies about the typical lengths of each age class. This was the length frequency method which is still so much used today because of its convenience of application to large numbers of observations, but because of the fact that the rate of growth of fishes slows down so markedly after reaching maturity this graphical method is limited in its application for individual age classes in the older fish are merged in an indistinguishable mass when their sizes are overtaken by the younger classes.

The length frequency method, although still of wide use for the analysis of size composition, was soon displaced by the more exact and useful method of age determination first developed in 1898 by Hoffbauer, who established the fact that the age of carp could be determined by a microscopic examination of the scales. (See Van Oosten, 1929.) Direct observation and careful experimentation has established the scale method as having universal application to fishes, but because of special circumstances, it is not always practicable with all species. For example, the plaice of the North Sea possess scales that are extremely difficult to interpret and more success has been had in age determination by a study of the structure of the otoliths or ear bones. The same is true of the American halibut (Thompson, 1915), and the scales of the Pacific sardine are illegible.

Throughout the past twenty years, however, the method has been greatly refined. Following Hoffbauer's early announcement, Walter in 1901 discovered that the relative width of a growth zone on a scale was proportional to the growth of the fish in that year. This significant contribution to the method was first studied critically by Lea, in 1910; using the

Norwegian herring and from his work we have the familiar scale formula, "Length of scale included in the annulus of year X, divided by the total length of the scale equals the length of fish at the end of year X, divided by the length of fish at the time of capture." Subsequent studies have shown that this is not a constant relation. It was soon criticised by Lee, in 1912, from which we have the "phenomenon of apparent change in growth rate." Gilbert (1913) readily adapted and developed the scale method for the age analysis of the annual spawning runs of Pacific salmon and opened the way for acquiring an understanding and control of the important salmon fisheries of Alaska. Harold Thompson (1919), studying the haddock, has found that the relative growth rate of scales of fish fluctuates from time to time throughout the season. The same phenomenon has been studied many times since and various corrections in the formula have been proposed. R. A. Nesbit of the staff of the Bureau of Fisheries, studying the scales of the weak fish, is making further contributions and refinements in the method at the present time along these lines.

The scale method, therefore, which provides information regarding the age of the fish at time of capture, its rate of growth throughout its life history, and in many cases, as in the Pacific salmon, records of peculiar environments by which distinct races may be identified from peculiarities in scale structure, has come to be one of the most important methods of fishery research and has produced a voluminous literature.

One of the important factors affecting the abundance of fish in any locality is migration which may be periodic and extensive, affecting the entire stock, or casual and local, affecting only portions of the stock. Certain fish such as the

herring can not be considered as uniform in the whole area of their distribution but may be distinguished as local forms or races because they spawn regularly at a certain season or at certain spawning places under definite physical conditions and later commingle in a general feeding area or on the other hand remain segregated throughout life with little or no intermigration. It is a well-known fact that within the same species the isolation of particular stocks of fish tends to develop differences in their physical characteristics or in their physiological reactions. These differences may be entirely the direct result of environment or they may be inherited, but if the stocks are isolated in origin the means and distributions of a series of measureable characteristics differ significantly whereas if intermingling occurs no such average differences remain.

Migrations of fish and the identification of segregated races have been investigated by means of morphometric studies of these local forms. Various structural characters have been used and analyzed statistically such as the counts of the vertebræ, dorsal or anal rays, gill rakers, keeled scales on the herring, and the proportions of the body such as the ratio of head length to standard length and similar proportions. This method has been applied with considerable success in the North Sea and in the Atlantic, to such fishes as the herring, cod, sardine, and other food fishes (International Council, 1929) and the Pacific herring (Rounsefell, 1930). In the last mentioned species Dr. Rounsefell of this bureau has distinguished twelve or thirteen separate races from California to the end of the Alaska peninsula.

Direct methods of tracing migrations include tagging and marking. One of the earliest methods of tagging fish was employed by the Scottish Fishery Board for marking plaice. The identifying mark

consisted of two disks of ebonite, bearing serial numbers attached to the fish by a silver wire through the body below the dorsal fin. This tag has been modified many times and is still used today (International Council, 1932). In America a modified form made of celluloid or aluminum bearing complete instructions for return of the tag is being used for cod, haddock, scup, flounders, and croakers on the Atlantic Coast. A metal strap tag of a different form has been used extensively for studying migrations of the cod (Schroeder, 1930) and the Pacific salmon (Gilbert, 1924). Nesbit's new belly tag, a celluloid strip bearing full instructions for return, inserted in the body cavity of the fish, is a startling new development in tagging method that holds great promise.

Aside from the attachment of numbered tags, the most successful method of marking fish is by clipping combinations of fins so that mutilated individuals in different experimental lots can be identified later. This method has been used extensively on the Pacific salmon to mark lots of young fish in the fingerling stage when liberated from hatcheries to trace their migrations and to test the effectiveness of artificial propagation (Rich and Holmes, 1929), and also for marking down stream migrants in nature to provide a mathematical basis for calculating the numbers of progeny from known escapements of spawning fish.

It is a certainty that one of the main factors affecting the quantity and size composition of the stock is the intensity of fishing. Direct evidence of this is afforded in some species by marking experiments. Thus it is definitely known in the plaice of the North Sea that up to 50 per cent or more of the marked fish may be recaptured in a year by fishing vessels. This is generally regarded as an unusually high rate of capture. Figures

cited by Van Oosten (1929), however, indicate that the annual mortality of the lake herring in Saginaw Bay may reach 70 per cent, of which doubtless the greater part is the result of commercial fishing. In the herring of northern Europe indirect methods of calculation have indicated mortality rates in the commercial stock of 20 per cent per annum in the Norwegian spring fishery, and 50 per cent per annum in the East Anglian fishery.

A striking object lesson on the influence of fishing upon the abundance of the stock is provided by the history of the fishery of the North Sea during the War (Borley, 1923). Fishing operations were naturally much restricted during these years and landings of bottom fish fell to less than 30 per cent of the normal amount with the result that the mortality rate due to fishing was materially decreased. During these years more fish survived, stocks were gradually built up, so that when fishing was again eventually resumed landings were considerably higher, and the average size of the fish somewhat greater. The increased yield did not, however, last very long, and the very intensive fishing of the years immediately after the War quickly wiped out this accumulation of stocks with the result that the landings per unit time fell to approximately the pre-war level.

The effects of this partial protection of the stock of plaice in the North Sea during the war period were very thoroughly investigated by the British Ministry of Agriculture and Fisheries, and it was found that by the end of the war the plaice stock had reverted some way towards the state of an unfished or virgin ground. Under such conditions catches are very high, but they consist of large, old fish in rather poor condition, which represent the accumulation of years. As time goes on these old fish are eliminated. The

average catch decreases with the average size of the fish, but their quality and their rate of growth is improved and more room is left for the up-growth of new stock. This is precisely what happened in the North Sea during the war and serves to emphasize the extreme complexity of the problem of overfishing. Parallel conditions exist in the Pacific halibut fishery as mentioned above.

Commercial interests in this country have advanced the proposal that overfishing need not be investigated, and that any regulation whatever of the intensity of fishing by governmental means is unnecessary on the grounds that the level of abundance of the fish supply will fall to a certain point known as the "least economic level," beyond which it would be unprofitable to exploit the fishery by any but the most efficient business units, and that the strain of fishing will thereby be relieved (Taylor, 1930). This is doubtless true, but we have no assurance that the least economic level will be the most productive one in food for the nation. Obviously, that level of abundance should be maintained that will induce maximum growth and replacement coincident with the greatest withdrawals from the supply that can be taken year by year without jeopardizing future production.

Since it is impossible to predict in advance the strain of fishing that any stock can withstand without permanent impairment, the study of overfishing is reduced to a routine of continuous observation in which the trend of the supply and the composition of the stock are given proper attention and analysis.

FLUCTUATIONS AND PREDICTIONS

The expression "fishermen's luck" summarizes the fact that the yield of the fisheries both locally and over wide areas is extremely erratic and a great mass of

scientific evidence now available indicates that these changes in yield are primarily due to major fluctuations in the actual abundance of the various fish stocks. These variations in abundance are also found in land animals, and attempts have been made to discover cyclic variations related to world-wide factors such as solar variations and the like. The problem has a very practical bearing. In certain communities, in northern Norway, for example, where the population is mainly dependent upon the fisheries for a livelihood, the success or failure of the fishing is, or used to be, a matter of life and death.

"It is natural therefore," says Dr. Russell (1932, p. 136), "that the study of fluctuations was tackled first and most energetically in Norway under . . . the direction of Dr. Johan Hjort, then director of fisheries. . . . It happened fortunately that at the time Hjort's work started (in 1901) the technique of age determination in fish by means of scales and otoliths was just being worked out. This method was applied with great success to the study of the herring, and it soon became established that the main cause of the fluctuations in the great spring herring fishery was the success or failure of the individual broods or year-classes composing the stock. Thus it was found that the 1904 year-class was remarkably abundant, and it predominated in the catches for many years, providing a rich fishery. It still persisted, though in greatly reduced numbers, for some years after the war, and meanwhile the stock was replenished by other good year-classes such as those of 1913 and 1918; intermediate year-classes were very poor.

"Similar methods applied to the Norwegian cod, supplemented by extensive measurements, demonstrated the existence of especially prolific brood-years, as for example those of 1904 and 1912, while other years contributed little to the stock.

"The same general method of determining the age-composition of the stock, and particularly the abundance of the incoming year classes or recruit-stock, has been used with success also on the North Sea, particularly by Dr. Harold Thompson for the haddock and by Dr. Hodgson for the East Anglian herring fishery."

Indeed, the problem of large scale fluctuations ever since the publication of

Hjort's paper of 1914 has received much attention from fishery investigators in Europe and has been actively studied as shown by the papers of twenty authors, published by the International Council (1930), under the title, "Fluctuations in the Abundance of the Various Year Classes of Food Fishes."

In America the study of these fluctuations in abundance forms the major activities of the research staff of the Bureau of Fisheries in the North Atlantic area and is being applied to the haddock, mackerel, scup, and weakfish. There can be no doubt that this general principle applies to the supply of all fishes, but probably the most spectacular variations in abundance are found in the mackerel fishery which has been studied for several years by O. E. Sette of the Bureau of Fisheries (*vide ante*).

From a study of the age-composition of the commercial catch of mackerel, together with the records of landings, data have been secured which indicate that the year-class produced in 1923 was extremely abundant. Probably the next in order of abundance was the year-class produced in 1928. The 1929 and 1930 year-classes were relatively less important and reproduction in all of the other years since 1923 was a virtual failure. So abundant, indeed, was the 1923 year-class that it largely dominated the fishery up to and including 1932, the most recent year for which an analysis is complete.

On the basis of these studies in which the relative strength of the various year-classes is calculated, together with their rates of decline, predictions of the expected yield have been offered for several years. These predictions have great potential value to the fishing industry. If a season of unusual abundance may be foreseen, marketing channels may be prepared for expanding distribution, and the technological processes such as freezing,

salting, canning, and packing may be planned to take care of the excess production, thus reducing glutted and demoralized markets, which too often drive prices so low as to cause real distress among the fishermen. Conversely, in seasons when scarcity appears inevitable, the cost of such preparations can be saved and accumulated stores of processed fish may be released to supplement current production.

Although no reports have been published, similar predictions have been prepared for several years for the major runs of salmon in the important fishing districts of Alaska. Strangely enough these predictions are based on less precise data than are available for the pelagic sea fisheries. They include such factors as the known escapement of spawning salmon and their age-composition, the physical conditions upon the spawning beds, the estimated production of young salmon migrating seaward, the normal age at maturity, and various other indications such as, for example, in the red salmon, the number of grilse or precocious males returning in the year previous to the year of prediction, which is believed to bear a fairly definite relation to the number of normally maturing adults. These predictions are becoming increasingly accurate and already have provided such valuable information that they are accepted as an important basis for the regulation of the fisheries by the Government and for the commercial preparations for packing activities the ensuing year. There is no doubt that additional research along these lines will bring still closer the practical control of fishing operations and the maintenance of the stock of fish.

Little is known so far about the causes of these fluctuations in the great fisheries. One thing appears reasonably certain: that there is no necessary correlation in the

case of pelagic fishes between the numbers of eggs produced in a particular spawning season and the number of fry which survive. On the contrary, good brood years have often been poor spawning years. The fate of the year-class is probably settled at a somewhat later stage, possibly in the larval or post-larval stage. Various factors have been adduced as probably affecting survival—lack of planktonic food for the newly hatched larvae, variation in temperature, variation in normal courses of currents drifting the larvae to localities unsuited to their growth and development. Much work still remains to be done before this complex problem can be solved and here is introduced to the field of fishery biology the great range of studies included in oceanography and limnology, the embryology and physiology of development, etc., that may have been regarded as basic or foundational studies or, indeed, only remotely related to fishery biology. Clearly the problem is an ecological one and nothing short of a full knowledge of conditions of existence of the species concerned, of its relations to other forms of life, of its food and competitors, will suffice to solve it.

FISHERY MANAGEMENT

Space will permit but a few remarks on the subject of protecting or wisely using the fish supply even though this subject represents the cutting edge of the tool of which the more technical phases of fishery biology are the handle. Certainly, the application of our knowledge of the status and trend of fishery resources, their natural fluctuations in abundance, and the life history and habits of the fishes they represent, must be applied in maintaining and utilizing the wealth of the waters. Doubtless, it is because of the youthfulness of fishery biology itself that the methodology of fishery conservation is so little

developed. The protection of the fisheries even where depletion is clearly evident is still very largely a matter of trial and error with uniformly too little effort applied to observing or correcting the "error." It is in this field that the fishery biologist is most directly confronted with problems in economics, for the protection of a fish supply is accomplished by the regulation of the business enterprise of fishing which in turn affects a series of related industries.

As pointed out by Thompson (1919) the application of corrective or preventive measures for the protection of a species threatened with depletion is dependent upon the nature of the species to be protected. One of the important considerations in this connection is the extent of migration which occurs, for if the species ranges over a wide territory regulatory measures must be applied over the entire range. On the other hand, if a species is largely localized, or is composed of segregated populations or races, protective measures may be applied only to those areas where the fishery is prosecuted most intensively, or, in case depletion is more general, closed areas may be established and alternated after a period of years with the areas in which fishing is permitted so as to provide a rotation that will favor natural recuperation of the species during the seasons of closure.

Conservation authorities are continually confronted with demands to prohibit fishing particularly in inshore waters during spawning seasons, to prohibit the capture and sale of immature sizes, to regulate or prohibit the use of efficient and, therefore, "destructive" types of fishing gear, or to close certain areas to commercial fishing. Many of these demands are certainly based upon economic reasons rather than biological, for in general fishing during the spawning season is no

more destructive to the species than at any other time of the year, barring the increased expectancy of survival until spawning as hazards of life are passed.

This is a subject on which there is very general popular misunderstanding. Arguing from the familiar domestic animals and game, it is generally believed that breeding individuals are somehow particularly vulnerable and therefore should be given special protection. Since the survival of any species depends upon the production and survival of a sufficient number of eggs, it is important to determine, as pointed out by Herrick (1911), "the life rate or law of survival," which is a measure of the hazards which must be survived by the progeny of each pair of adult individuals. The reproductive capacity of any individual is measured by the total number of eggs produced in the average life time, and the destruction of these eggs is equally as serious in the case of catching an immature fish in its early stages of development as it is just prior to actual spawning. The worth of an individual to the species for the purpose of reproduction, however, as measured by the life rate or expectancy of survival increases as the spawning period approaches and as the dangers of destruction are surmounted. As Thompson (*loc. cit.*) says, "The question is simply one of where it is best to take toll of the supply, considering first the survival of the species and then the age or time at which the available surplus may best be taken. Is it best to take the immature before the natural perils of the sea have reduced their numbers or to take the mature after they have increased greatly in average size? . . . In other words, which has the least value to the species weight for weight?" Of course, certain species that school densely for spawning are more readily taken at that time. Fish taken at the spawning time or immediately after are

inferior in quality as a food product and, in species for which there is an active demand for roe, spent fish have naturally a reduced value and hence their protection at that time is based on economic considerations.

There are economic reasons also for preventing the sale of small fish for they usually bring lower prices, although the same frequently applies to the largest specimens as well. Closed seasons at various times of the year other than the spawning period are frequently demanded in order to prevent the taking of an over-supply that will demoralize markets and reduce profits, and closed areas are frequently designed to prevent the taking of large quantities of small fish having little market value. Because these demands are economic rather than biological, they are often frowned upon by professional conservationists, but, as in the utilization of any other food animal, the principle should apply to the fisheries that the individuals of a species should not be taken until they have passed the period of maximum growth, and until they have reproduced a sufficient number of times to maintain the species. They should be taken at the time when they have the highest market value and the greatest food value. Even this principle is not always applicable, for some species such as the shrimp of the South Atlantic States are utilized chiefly when immature.

With these principles in mind we may again consider the protection of undersized fish. Most of these if spared would grow to marketable size. Common sense indicates that such protection would increase the yield of marketable fish, but the problem is not so simple as it seems, for the question of degree comes in. Possibly thinning out the stock at a very early age might be very advantageous while thinning later on might be disastrous

depending, of course, upon the period in the life history of the fish during which greatest natural mortality occurs. The problem is to some extent susceptible to exact mathematical treatment if we know certain fundamental food ratios, namely, the amount of food relative to body weight required to keep weight constant, and secondly the relation between growth in weight and the amount of food required to produce this growth. Experimental studies on this subject have been carried out at the Plymouth Laboratory in England (Dawes, 1930, 1931), but little investigation of this type has been conducted in America.

The question of the adequacy of the food supply has been studied in Europe by Peterson (1918) and others, but in America it has been assumed generally that the food supply is normally super-abundant for the existing fish population, and on this basis the Bureau of Fisheries has been devising commercial gear that will permit the escape of a large proportion of undersized fish from the trawl catches of haddock in the North Atlantic and from the pound net and gill net fishery in the Great Lakes (Higgins, 1933). We have no assurance, however, that such measures will be adequate to stay the threatened decline in these fisheries.

In Alaska the protection for the salmon runs has been effectively provided by limitation upon the commercial catch. The number of salmon traps is limited indirectly by locality restrictions, and the fishing period for all types of gear is restricted to but a portion of each week. In this way at least one half of the total run of salmon is permitted to escape the fishing gear and enter the rivers for spawning. Recent observations, however, indicate that a far better means of conservation would be to require by law the escapement of a definite number of salmon, adjusted

according to the capacity of available spawning grounds rather than to protect a fixed percentage of the total run.

Protection of the halibut fishery of the North Pacific through authority of the international treaty is provided by an arbitrary limitation of the quantity of halibut that shall be landed from the various areas into which the fishing grounds are divided for statistical purposes. Quotas are assigned to each of these areas that may not be exceeded by the fishing fleet and when that yield is attained all fishing ceases for the year. Through careful study of the effects of such limitations by the fishery commission and through the enforcement of proper regulations, the decline in abundance can certainly be stemmed although, because of the slow growth of the species, many years will be required before recovery of the stock will be apparent.

Experience is too limited to permit the expression of general principles or laws universally applicable to fishery conservation. In general, however, it is admitted that, since the depletion of stocks is almost uniformly the result of overfishing, the remedy lies in reducing the strain of exploitation. How this may best be accomplished depends upon a variety of local circumstances which the fishery biologist must take into account even

though they frequently lie outside of the conventional field of biological investigation.

In the foregoing pages, I have cited the views of many workers and referred to the more recent literature in an attempt to define the boundaries of the current and the central drift of fishery science in the sea of marine biology.

It may be seen from the evidence here presented that fishery biology no longer includes the diffuse and nebulous aims of the older students of natural history in which every fact concerning fish and their environment is regarded as having equal importance and being equally worthy of study. If another international fishery conference were to be held at present no such general program as that of 1908 would be arranged. Different sections would doubtless be organized including separate discussions of fishery technology, aquiculture, and fishery biology at least. Investigators of fishery problems may not have narrowed their interests, but they have defined more clearly than ever before their objectives and have concentrated their efforts upon the more immediate and practical demands of industry to define and recognize overfishing and to manage rationally the fish supply for the permanent good of humanity.

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PROPERTIES OF WATER OF BIOLOGICAL INTEREST

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INTRODUCTION

THE peculiar fitness of water as a medium for life is a subject which has received much attention for a number of years (Henderson, 1914, 1927; Bayliss, 1927). If one were to describe, on theoretical grounds, the supposed properties of the substance H_2O , these properties would differ widely from those of the substance we know as water. The boiling point, for instance, should theoretically be $-100^{\circ}C.$ and the melting point $-150^{\circ}C.$ (Duclaux, 1912, p. 882); however, these values for water are respectively 200° and 150° higher than the theoretical ones. Other peculiar properties of water are its anomalous variations in specific heat, its high heats of fusion and vaporization, its maximum density at $4^{\circ}C.$, its anomalous thermal expansion, its minimum of compressibility at $50^{\circ}C.$, its high surface tension, and its changes in magnetization constant. All of these abnormalities can be explained only on the supposition that water is highly polymerized (i.e., composed of H_2O , $2H_2O$, and $3H_2O$, etc.) and that the ratio of these polymers changes with change of temperature or that the molecules are arranged in a complex which changes with temperature. For example, the maximum density at $4^{\circ}C.$ can be explained by the association theory, for, superimposed on the normal thermal expansion curve is a contraction curve due to the conversion of bulky ice (trihydrol) molecules into the denser dihydrol molecules, the effect of the two processes on the total volume

being equal and opposite at $4^{\circ}C.$ Concerning this effect Tyndall (1889, p. 120) wrote "this halt [in contraction] of the approaching molecules at the temperature of $39^{\circ} [F.]$ is but a preparation for the subsequent act of crystallisation."

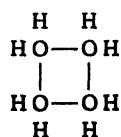
In previous papers (T. C. Barnes, 1932; H. T. Barnes and T. C. Barnes, 1932; Lloyd and T. C. Barnes, 1932) it was reported that filaments of *Spirogyra*, especially *S. nitida*, would live longer in water which had recently been ice than in water which had recently been condensed from steam (water changed daily in both cases). The working hypothesis was suggested that the polymerized molecules (trihydrol) were factors conditioning the observed difference. However, in *Spirogyra* neither the general appearance of the cells nor the extent of the mass of filaments permits quantitative studies. We have performed similar experiments with a protozoan, *Euglena gracilis*, in which it is possible to determine the number of individuals per ml. of water (T. C. Barnes and Jahn, 1933).

No extensive review of the association of water has appeared for twenty-three years (*Trans. Far. Soc.*, vol. 6, 1910, p. 85) and it seems desirable that a review of the more important phases of this subject be made available to biologists. The present paper gives a review of the association of water and its isotopic composition, particularly from the viewpoint of the general physiologist, together with certain data on the effect of ice water on *Euglena*, and further data on the rate of freezing of ice water and steam water. The rather over-

ous "library work" was found necessary in connection with replies to numerous and stimulating criticisms of the trihydrol hypothesis in biology (cf. T. C. Barnes, 1934b).

EARLY WORK

The best short résumés of the association of water are those of Duclaux (1912), Turner (1915), Mellor (1922, pp. 411-421), Friend (1924), Chadwell (1927), H. T. Barnes (1928) (Bibliography), Longinescu (1929) and Honigmann (1932). It is not generally known that Whiting (1884, p. 71) was the first to develop a theory postulating the presence of dissolved ice particles in liquid water at all temperatures. Whiting believed that in freezing water there might be somewhere between 25 and 38 per cent dissolved ice, and in boiling water somewhere between 17 and 23 per cent. He also believed that the true expansion of water (apart from the contraction caused by the melting of dissolved ice) between 0°C. and 100°C. was not only 4 per cent but probably 8 to 10 per cent. In the same year Raoult from a consideration of the freezing point of solutions pictured the water molecules in groups of four which he later (Raoult, 1895) considered to be groups of twos. Vernon (1891) explained the temperature of maximum density of water by postulating that the water molecules aggregate together and form more complex molecules than before existed. The density begins to decrease when about half of the molecules have undergone aggregation. Water from 100° to 4° has the formula $(H_2O)_2$ and below 4° these molecules will condense to $(H_2O)_4$ molecules which Vernon pictures as:



Röntgen (1892), in a paper which Sutherland describes as "elegant but brief," independently proposed that water contains dissolved ice particles, and he used this hypothesis to explain several of the unique properties of water. On this assumption the decrease in the compressibility of water from 0° to 50°C. is due to the smaller percentage of bulkier ice molecules as the temperature is increased. Röntgen also refers to Amagat's demonstration that the expansion coefficient of water between 0° and 10°C., 0° and 30°C., and 0° and 50°C. increases with pressure up to 2500-3000 atmospheres and is greater at lower temperatures. This is in contrast to simpler liquids such as ether and alcohol whose coefficient of expansion decreases with pressure. Röntgen's third point is that the viscosity of water can be decreased by pressure, while that of most simple liquids is increased under pressure. Pressure dissociates the viscous trihydrol which may more than compensate for the usual increase of viscosity with pressure. The two effects are equal at about 30°C. (cf. H. T. Barnes, 1928, p. 40). The phenomena can be explained on the assumption "dass flüssige Wasser aus einem Aggregat von zwei Arten verschieden constituirter Molecule besteht."

Van Laar (1899) in a mathematical paper on the association of water and of alcohol considered fluid water as a system of single and double molecules (Table 1) and explained the contraction of alcohol-water mixtures as a dissociation effect (but cf. Bancroft and Gould, 1934).

Probably the most extensive and at the same time the most speculative paper is that of Sutherland (1900), who calculated the percentage of trihydrol at various temperatures. It must be remembered that Sutherland held to the binary theory of the association of water, postulating that the liquid form is composed of trihy-

drol and dihydrol only. Later work, however (Callendar, 1902; Bousfield and Lowry, 1905; Rao, 1934), indicates that water is a ternary system containing hydrol or steam molecules, at least in the range of 60° to 100°C. Southerland

or that the density (ρ) is a linear function of the temperature. Expressed graphically, with t as abscissa and ρ as ordinate, the equation gives a straight line for ordinary liquids, but the corresponding graph for water is a curve with a maximum

TABLE I
Percentage of Trihydrol at Different Temperatures According to Various Authors

Whiting (1884), p. 71.			
STATE OF WATER	MELTING ICE	FREEZING WATER	AT 100°C.
% "solid particles"	About 50-70	About 25-35	About 17-23

van Laar (1899), p. 6.

Temp. °C.....	20°	100°
Fraction of "Double Molecules".....	4/5	3/5

Sutherland (1900), p. 464.

These values give a smooth curve when plotted against the temperature shift in the infra-red bands of Plyler at 1 and 1.2 μ (Cf. H. T. Barnes, 1928, p. 85).

Temp. °C.....	~	~	~	~	~	~	~	~	~
% Liquid Ice.....	37.5	32.1	28.4	25.5	23.4	21.7	20.3	19.1	16.5

Duclaux (1912).

Temp. °C.....	0°	100°
Grams of ice per liter of water.....	200-300	50

Richards and Chadwell (1925), p. 2293.

Temp. °C.....	0°	20°
% "polyhydrol".....	39	28

Tammann (1926).

Temp. °C.....	0°	10°	20°	30°	40°
Proportion of molecules of Ice I per gram of water.....	0.15	0.12	0.08	0.06	0.04

Rao (1933).

SUBSTANCE	ICE	WATER AT 0°	WATER AT 4°	WATER AT 38°	WATER AT 98°
% H ₂ O	0	19	20	29	36
% (H ₂ O) ₂	41	58	59	50	51
% (H ₂ O) ₃	59	23	21	21	13

calculates the densities and properties of his two ingredients on the assumption that each constituent follows Mendeleeff's law of expansion of liquids between 0°C. and their boiling points, that is,

$$\rho = \rho_0 (1 - kt)$$

density indicated at about 4°C. At higher temperatures Sutherland's curve approaches asymptotically the straight line for a simple liquid. Therefore he assumes that the asymptote represents the behavior of one of the pure ingredients of water (di-

hydrol). By analysis of the curve he finds that water at 0°C . consists of 37.5 per cent liquid (H_2O)₁; density 0.88, and 62.5 per cent liquid (H_2O)₂, density 1.09 (*vide* Table 1). The latent heat of fusion of trihydrol, 16 calories, is calculated on the assumption that it would expand 0.0366 on fusing, 0.0366 being the mean expansion of a number of metals. The average expansion on melting of solids such as Pb, Cd, Sn, Na, K, P, and Hg (data of Vincenzini) is 3.3 per cent, while in the case of water there is a contraction of 8.3 per cent. This difference led Sutherland to believe that "the solidifying of water into ice is no mere physical change of state, as with most melting bodies, but is chiefly a profound chemical change." The remainder of the latent heat of fusion of ice is supposed to be made up of the *heat of dissociation* of 62.5 per cent of the ice into dihydrol and the heat of solution of the remaining fraction (37.5 per cent) in dihydrol.

Sutherland supports these conclusions by appealing to the then existing data on optical refraction, compressibility, surface tension, specific heat, viscosity, and dielectric capacity, all of which, with the possible exception of the last, appear to vary with temperature according to Sutherland's scheme of the changing proportions of ingredients.

From the standpoint of general physiology Sutherland's speculations concerning the surface tension are of extraordinary interest. According to Eötvös, if Mv is the molecular volume, α the surface tension, and $\alpha(Mv)^{2/3}$ the molecular surface energy, σ , then $d\sigma/dt$ is nearly the same for all normal liquids and remains almost constant (2.12) until the critical temperature is closely approached. For associated liquids of varying degrees of association, $d\sigma/dt$ is not constant and is of a lower value than for unassociated liquids. Since this

value for water ($M = 18$) near 0°C . is about 0.92 (data of Ramsay) and rises with temperature, it is assumed that water is associated and that an increase in temperature results in a decrease in the amount of association. In order to bring the value of Eötvös' constant nearer to 2.12, it is necessary to multiply by $3^{2/3}$, thereby assuming that the surface layer is $3\text{H}_2\text{O}$ or that it has an average molecular weight of 3×18 . This gives 1.91, and a further correction for density necessitates multiplying by $(1/0.88)^{2/3}$, where 0.88 is the derived density of trihydrol (*vide supra*). This factor raises 1.91 to 2.08, a figure near enough to 2.12 to suggest that the surface film of water at about 0°C . consists *entirely of trihydrol*. Thus it appears that the tension in the surface layer of water at 0°C . is sufficient to cause nearly all of the water there to change into trihydrol, the surface tension of which is that of water at 0°C ., namely, 73.32 dynes per cm. This appears logical enough, for if compression dissociates, tension might be expected to associate the water molecules. By Eötvös' relation the surface tension of trihydrol at any temperature is given by the equation:

$$\alpha_2(54/\rho_2)^{2/3} = 73.3(54/.88)^{2/3} - 2.12t$$

Sutherland's calculations indicate that up to 40°C . the surface film of water consists of pure trihydrol, but that at 60°C . and higher temperatures the surface tension is so much reduced as to allow some of the lower polymers to form. However, in this connection we must remember Nernst's (1923, p. 322) suggestion that although deviation from the constant of Eötvös indicates association of a liquid, it is impossible to conclude satisfactorily the *precise degree of association*. Shereshevsky's (1931) recent modification of the Eötvös equation has not yet been applied to associated liquids. Adam (1930, pp.

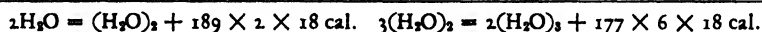
153-155) discusses the value of Eötvös' law and considers cases where it cannot be applied.

Sutherland also suggests that the empirically well known properties of surface tension of aqueous solutions must be due largely to the difference between the surface layer and the body of the water and to the dissociation of some of the trihydrol by solutes. This was demonstrated later by Bousfield and Lowry (1910). Sutherland points out that the solubility of substances in trihydrol may be different from

lendar (1902) and H. T. Barnes (1902) in their studies of the variation in specific heat of water with temperature (Table 3). Callendar (1902) was quite critical of Sutherland's interpretation of the specific heat of water. Sutherland, assuming the usual rate of increase of specific heat of a liquid (0.1 per cent per degree), calculated the specific heat of pure dihydrol and of pure trihydrol to be 0.83 and 0.6, respectively, at 0°C. He explained the remainder of the specific heat of water as being due to the heat of dissociation of part of

TABLE 2
Physical Constants of Water Polymers. (Sutherland, 1900)

CONSTANT	DIHYDROL	TRIHYDROL
Density ρ at 0°C.....	1.08942	0.88
Temp. coeff. of density, k	0.0009	0.0002
Compressibility per atmo. at 0°C.....	0.000016	0.000010?
Surface tension at 0°C.....	78.3	73.32
Critical temperature.....	368 C.	538 C.
Specific heat at 0°C.....	0.8	0.6
Latent heat of fusion.....		16 cal.
Latent heat of evap. at 100°C.....	257	250 (near)
Viscosity at 0°C.....	0.0030	0.0381
Pressure-coeff. of viscosity per atmo.....		0.00034

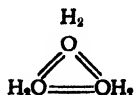


Addenda:

Rate of dissociation of one gram of trihydrol by pressure (grams per atmo.) at 0°C., 0.00017; at 100°C., 0.0001

Recession of temperature of maximum density with pressure = 0.025°C. per atmo. (Amagat)

that in dihydrol and that a re-examination of surface tension of solutions from this viewpoint would be of great interest. Finally, he proposes a following structural formula for trihydrol:



The physical constants of Sutherland's polymers are given in table 2.

SPECIFIC HEAT

The existence of dissolved polymers in liquid water is briefly considered by Cal-

endar (1902) and the heat of solution of the dihydrol thus formed. Callendar put forward the suggestion that the high specific heat of water may be due to "internal work done against molecular forces, and as being closely related to the decrease of latent heat of vaporization with rise of temperature." Further details of this line of argument may be obtained from the original paper (pp. 146-148). Callendar, however, was the first to postulate the existence of steam molecules in liquid water, and since his time the ternary theory of the constitution of water has been widely accepted. Water,

according to this theory, is composed of monohydrol, dihydrol, and trihydrol, and the ratio of these substances varies with the temperature. The amount of trihydrol decreases as the temperature is raised above the freezing point, and the amount of monohydrol decreases as the temperature is lowered from the boiling point. In this way Callendar explains the increase of specific heat as the freezing and boiling points are approached; this theory also accounts for the anomalous expansion. Recent papers by Callendar (1929) deal with the properties of

abnormality which H. T. Barnes suggests might be due to the interesting possibility "that water commences to anticipate the solid phase, even before 0° is reached."

In the same paper H. T. Barnes gives an interesting quotation from Rowland's (1879) early work on the specific heat of water. Rowland points out that the decrease of specific heat with rise of temperature is no more remarkable than the contraction to 4° and "in both cases the water hardly seems to have recovered from freezing" (p. 131). This is, in all probability, the first suggestion which could be interpreted as indicating the presence of trihydrol in water, although Rowland unfortunately is not clear concerning his identification of latent heat and specific heat. Henry (1905) points out that water is formed from two perfect gases, one H boiling at -253° and the other O at -184° which unite to form a liquid boiling at 100° which indicates polymerization. According to Longinescu (1929), Henry was the first to propose the general theory of association in liquids.

Hudson (1905) explained the constant temperature of freezing by assuming that the ice molecules have a definite solubility in water as well as a definite equilibrium concentration varying with temperature. A second substance decreases the amount of ice molecules, making it necessary to cool the solution before equilibrium concentration reaches the saturation point of the ice molecules.

SOLUTION VOLUME

Bousfield and Lowry (1904) made a careful study of the solution volumes (defined below) of NaOH with special reference to the effect of solute upon the water polymers. Their data support the ternary theory of water, and this interpretation is further supported by later experiments on the solution volume of several important salts and other substances (Bousfield and Lowry, 1910). Although not many, these range from the slightly hydrated chloral hydrate through AgNO₃, cane sugar, acetic acid, the physiologically important salts KCl, NaCl, and CaCl₂, to the strongly hydrated LiCl. The actual solution volumes of the physiological salts are much smaller than those of the organic compounds—only 0.24 to 0.35 cc./gm., but variations are much greater. The

TABLE 3

Variation of the Specific Heat of Water (selected values from the curve of H. T. Barnes, 1902, p. 252) to Show the Minimum

TEMP.	SPECIFIC HEAT
5°	1.00530
15°	1.00030
25°	0.99806
35°	0.99735
45°	0.99760
55°	0.99850
70°	1.00035
85°	1.00237
95°	1.00370

steam at great pressures and at temperatures far above the biological range.

The specific heat curve of H. T. Barnes (selected data in Table 3) shows a well marked minimum at 37.5°C. As we shall see later, other properties of water such as solution volume with certain salts have a critical temperature at this point. A possibly significant coincidence which has not been pointed out previously is that this is a typical mammalian body temperature. A rise in specific heat with rise in temperature (similar to that which occurs in water above 37.5°C.) is a general phenomenon in normal liquids, but the rise in specific heat of water as the temperature is reduced below 37.5°C. is an

curves for KCl and NaCl show a maximum solution volume at about 60°C., which is most pronounced in dilute solutions. The solution volumes of KCl are larger than those of NaCl, the solution volume of a 2 per cent KCl solution being larger than that of 10 per cent NaCl. The curves for CaCl_2 and LiCl are most abnormal and show maxima at 50° and 35°C., and these are more pronounced in 40 per cent than in 10 per cent solutions. This work is of special interest in general physiology, for the dissolved substances in organisms undoubtedly have a pronounced effect on the state of water in the tissues. Bancroft and Gould (1934) have recently explained the Hofmeister series of anions on the basis of the specific effect on water polymers. Also, the effect of salt on the water polymers determines in part the physical constants of sea water (e.g., absence of maximum density).

The method used by Bousfield and Lowry is essentially a comparison of the properties of water with those of a graded series of aqueous solutions of which water may be considered as a limiting member. The initial experiments with NaOH revealed that water is the most complex of the series, and that as the concentration of solute is increased the behavior of the liquid becomes increasingly simple. Thus the maximum in the density-temperature curve of water disappeared on the addition of 2 per cent NaOH; from 12 per cent up the relation is expressed by a simple parabola, and at 42.5 per cent the relationship between density and temperature becomes strictly linear from 0° to 100°C. These curves showed further that the abnormal properties of water were not confined to the vicinity of the freezing point. A second region of abnormality, not previously recognized, appeared in the neighborhood of 60°C., and developed with increasing magnitude as the boiling point

was approached. This was due to the production of steam molecules of simpler composition than typical water molecules but which, like Röntgen's ice molecules, possessed a greater specific volume. Increase of specific heat with temperature is a general phenomenon of normal liquids, and therefore previously observed increases in specific heat of water might have been explained by causes other than further dissociation, but the solution volume data of Bousfield and Lowry seem to be open to no other interpretation. These data are, however, easily explained on the basis of the ternary theory.

Bousfield and Lowry believe that their evidence for the ternary theory is much safer than that obtained by earlier workers with other methods. The term "solution volume" indicates the increase in the volume of the liquid which takes place when 1 gram of the solute is dissolved in a given volume of the solvent. Thus 1 gram of NaCl dissolved in 100 cc. of water increases the volume of the liquid to 100.2 cc., and the solution volume of the salt is 0.2 cc. per gram. A normal solution volume is the real volume of the solute in the liquid state diminished by any contraction which takes place on solution. Solution volumes vary with temperature and with the concentration of solute, and under certain conditions may be zero or even negative. For instance, it is possible to dissolve 140 gms. of NaOH in a liter of water at 0°C. or 100 gms. in a liter of water at 100°C. without increasing the volume of the liquid. In a simple liquid the thermal expansion proceeds in such a way that the rate of increase in solution volume becomes progressively greater as the temperature rises, so that normal solution volume-temperature curves should be of the same general character. A constant contraction (from the formation of hydrates) would affect only the *position*

and not the *form* of the curve. Therefore, the striking distortions actually observed must be attributed to variations other than the formation of hydrates. The simpler behavior of concentrated solutions indicates that the distortion of the solution volume curves must be attributed to the changing character of the water rather than to alterations in the hydration of the solute. These distortions are easily explained on the basis of the changing character of the water with temperature.

The fact that a contraction in total volume usually accompanies dissolution of a salt capable of hydration shows that water combined as hydrate has a greater density than the same water before it was combined. Contraction would result from the conversion of the bulkier types of molecule ("ice" or "steam") into the more dense ones of the hydrate. The density of combined water may be taken as 1.1 (KCl), which figure may be compared with 1.089 given by Sutherland for dihydrol. Contraction is maximum when the solvent is present in large excess, and variations in solution volume with temperature are largest in dilute solutions. If we compare solution volume curves of various solutes in the order of their affinity for water, the curves change from concave (chloral hydrate) to convex (acetic acid) and finally show a maximum (LiCl), and as the solutes have a greater and greater affinity for water, the maximum of contraction shifts to lower and lower temperatures. The lowest given minimum temperature for the maximum contraction is that of LiCl at 35°C., and it is interesting to note that this is close to the minimum in the specific heat curve (37.5°C.). Any further lowering of the temperature of maximum contraction would be rendered impossible by the increasing proportion of ice molecules in the solvent. It is clear that the existence of a temperature of maximum contraction in-

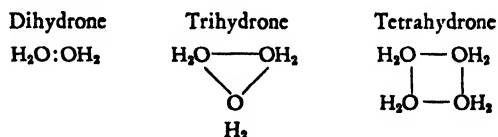
dicates a difference in the proportion of the bulkier ice or steam molecules. This firmly establishes the ternary theory of water.

POLYMERIC ISOMERISM

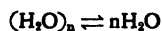
The interesting paper of Armstrong (1908) deals with the possible existence of isomeric water molecules of equal complexity but of different structure. Water itself is supposed to be a complex mixture of active and inactive molecules; the active molecules being either simple monad-hydrone (OH_2) molecules or hydrone-hydronol

(briefly, hydronol) molecules $\left(\begin{array}{c} \text{H} \\ \diagup \text{H}_2\text{O} \diagdown \\ \text{OH} \end{array} \right)$;

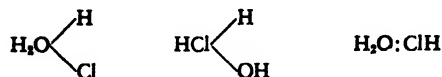
the inactive, the closed systems which are formed by *association* unaccompanied by *dissociation* of two or more simple molecules such as



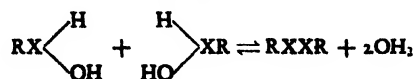
The dissociative change



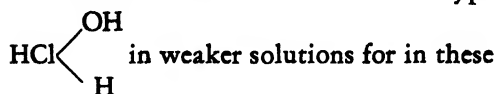
is of constant occurrence in water and is largely conditioned by the presence of dissolved substances. When a substance such as HCl dissolves in water the following complexes are produced



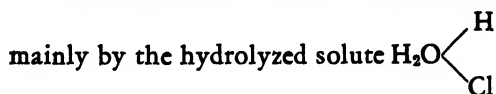
of which the first two are the only effective forms, the last being inactive as long as it remains closed. Through the agency of hydrol dissolved molecules may be converted into inactive isomerides:



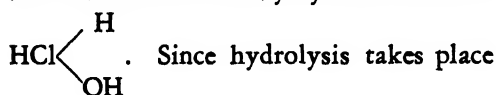
On dilution there is an increase in the number of effective composite molecules, ascribable to the diminution in the activity of the solvent water which is *most active when present in small amounts* (as it is then present in the monadic form or in association as hydrol). Thus we would expect to find molecules of the active type



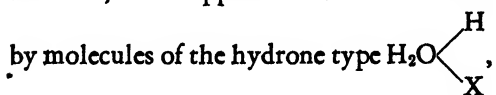
the monads of hydronol are scarce and the solvent has less tendency to withdraw hydrol from the complex. Conductivity in concentrated solutions is conditioned



but in weak solutions by hydrolated solute



more readily in the more concentrated solution, it is supposed to be conditioned



not by the isomeric hydrolated complexes. When discussing the behavior of non-electrolytes on a later page (p. 88) Armstrong mentions that pressure diminishes the rate at which cane sugar is hydrolyzed and the degree of hydrolation and hydronation of sugar is diminished by an increase of hydrol and hydrone resulting from pressure dissociation. The original paper must be consulted, for it is obscure on several points, but we have given enough of Armstrong's argument to illustrate the possibility that the "trihydrol effect" in biology may be traced to the distribution of the water ions in the molecules in protoplasm rather than to a direct effect of the water polymers.

A word must be said concerning Armstrong's treatment of surface effects which,

of course, are of peculiar importance in general physiology. Brownian movement effects, the evolution of heat on moistening powders, the decoloration of solutions by charcoal, the flocculation of colloids by salts, and the "dead space" of Liebreich are discussed from the standpoint that all surfaces in contact with water are hydrolated and in virtue of this condition they influence hydrolated molecules in the liquid, withdrawing elements of hydrol from them. Thus in Liebreich's phenomenon the dehydrolation of molecules near the surface of the tube (in "dead space") explains the greater activity toward the axis. But it is impossible to accept Armstrong's statement (p. 95) that "the phenomena of surface tension may be attributed to the preponderance of monads in the surface layer of a liquid," for we have seen that the trihydrol molecules of small density collect at the surface. Armstrong has previously stated that the monads are quite dense since they are concentrated by pressure, which is inconsistent with his view of surface films. Bousfield and Lowry's work later indicated that the water monads have less density than dihydrol. It is unfortunate also that Sutherland's calculation that water film is pure trihydrol is based entirely on the binary theory. One of us (T. C. B.) is at present investigating the appearance of algae on the surface of ice water and steam water, and it is found that *Ulothrix* on the surface film does not show the polymer effect seen in *Spirogyra* below the surface.

DEGREE OF ASSOCIATION

Guye, in the Symposium of the Faraday Society (1910), summarizes his work on the association of water and of other compounds. He asserts that molecular polymerization in the liquid state depends essentially upon chemical constitution and

that this fact is exemplified by association in the homologous series of aliphatic acids and alcohols. There are certain groups capable of polymerization (OH, CO, CN, NH₂, NOH, CONH₂), and substances with two polymerizable groups

that this might lead to the formation of highly complex and stable polyhydrols.

In connection with Guye's discussion of groups capable of association it is of interest to note that Bingham and Spooner (1931) have recently listed polar groups

TABLE 4
The Association Factor of Water, α in $n(\text{H}_2\text{O})_x$, According to Various Authors

Raoult (1885), $\alpha = 2$.			
Vernon (1891), typical water, $\alpha = 2$; aggregate at 4°C., $\alpha = 4$.			
van Laar (1899), $\alpha = 2$.			
Sutherland (1900), steam, $\alpha = 1$; water, $\alpha = 2$ and 3.			
Duclaux (1911).			
TEMP.	FROM COEFFICIENT OF EXPANSION	FROM COMPRESSIBILITY AND TEMPERATURE	FROM EXPANSION AND SPECIFIC HEAT
Apparently at 0°C.	$\alpha = 9-12$	$\alpha = 6-23$	$\alpha = 12$
Guye (1910).			
TEMP.	FROM COHESION FORMULA OF DUTOIT	SURFACE TENSION (RAMSEY AND SHIELDS)	SURFACE TENSION (RAMSEY AND INNES)
0°C.	$\alpha = 2.52$	$\alpha = 3.81$	$\alpha = 1.71$
60°	2.18	3.00	1.52
100°	1.90	2.66	1.40
120°	1.85	2.47	1.35
Tammann (1926), highest polymer in water, $\alpha = 9$ or 6.			
Pennycuik (1928), $\alpha = 6$.			
Stewart (1931), aggregate may contain hundreds of molecules.			
Kinsey and Sponsler (1933), $\alpha = 2$.			
Bernal and Fowler (1933), water structure based on a 4-conditioned aggregate, $\alpha = 5$.			
Bingham and Stevens (1934).			
Ordinary water, $\alpha = 2.5$. Heavy water, $\alpha = 1.34$.			

are as a general rule more highly polymerized than those with only one such group. This leads to the highly interesting suggestion that dihydrol is more apt to polymerize than hydrol, and under certain conditions it is possible to imagine

which accentuate association notably, OH, COO, NH₂, CO, Cl and SH.

Guye regards the association factor derived from the relation of molecular weight and surface tension as only approximate, and for calculation of the molecu-

lar weight of water he uses the formula of Dutoit and Mojoiu for liquids of mean volatility:

$$M = \frac{0.6 T (4.8 - \log P)}{a},$$

where a is the specific cohesion (defined as $a = br$, b being the height to which a liquid ascends in a tube of radius r , provided that the height b does not exceed 1,500 mm.). This formula gives a somewhat lower association factor (Table 4) than that derived from Eötvös' equation (*vide supra*). Guye concludes, however, that the coefficients from Dutoit's formula agree with the view that water at 0°C. is composed mostly of trihydrol and at the boiling point mostly of dihydrol. In considering these association factors (Table 4) it should be remembered that the factor for the highest polymer will be higher than the average factor indicated.

Rosenstiehl (1911), who studied the polymerization of water of crystallization, states that trihydrol is the commonest form of water in crystals containing large amounts of water and at low temperatures when the crystals separate out it is the most stable form of water. If this view were correct, one should expect that the molecular structure of trihydrol could be demonstrated by x-ray analysis. However, Chadwell (1927) points out that x-ray analyses of water of crystallization do not support Rosenstiehl's theory. Pennycuik (1928) believes the water of crystallization in a number of salts to exist as hexahydrol rings, $(H_2O)_6$, and this is in agreement with his view that the polymer in liquid water is also $(H_2O)_6$.

The most outstanding paper on the degree of association of water is undoubtedly that of Duclaux (1911) who, using new methods, calculated association factors much higher than 3 (Table 4), the factor assumed for trihydrol. He pointed out that on account of the lower density of dissolved ice, the proportions of the polymers should vary with the depth of water in a vertical tube. Furthermore, as a result of pressure differences the concen-

tration of liquid ice will be lower toward the bottom of the tube, and it will be related to the internal pressure of the liquid by the equation

$$\frac{dc}{c} = -4.5 \times 10^{-8} M dP$$

where M is the molecular weight of the dissolved ice, C its concentration, and P the pressure ($T = 0^\circ\text{C}.$).

Duclaux also points out that the molecular weight of a substance may be calculated from its coefficient of expansion, α . The equation is as follows:

$$\frac{0.97\alpha}{\alpha + 68 \times 10^{-6}} = 1 - 0.000785M$$

The coefficient of expansion of hydrol is unknown, but by assigning the probable limits 0.0004 and 0.0006, Duclaux calculates a molecular weight for dissolved ice of 164 or 218 depending upon the value of the coefficient used. These values yield the formulae $(H_2O)_9$ and $(H_2O)_{12}$, with molecular weights of 162 and 216, respectively.

As calculated from an equation relating the compressibility of water to temperature the molecular weight of dissolved ice lies between the limits 120 and 410, (suggesting $(H_2O)_6$ and $(H_2O)_{23}$) and depends upon the values assigned to the compressibility coefficient of hydrol. The value $(H_2O)_{23}$ is one of the highest ever proposed for associated water. However, the groups of water molecules postulated by Stewart (1931) may contain hundreds.

By combining the expansion formula with specific heat data Duclaux developed a third method of calculation on the assumption that the specific heat of ice is 0.6 and that it increases slowly with temperature. This treatment assigns to dissolved ice the formula $(H_2O)_{12}$. In all of the above cases, Duclaux admits he assumed that the density of ice does not

change on solution, and that (as Sutherland reasoned by analogy) a change probably does take place. Therefore, the exact figures of Duclaux are only of doubtful validity, but it is interesting to note that all of his values indicate that liquid ice is a much more complex molecule than trihydrol.

The degree of association of water has also been calculated from the depression of the freezing point when a solute of known molecular weight is introduced. In this method it is assumed that the solute is non-associated in solution, that no molecular complexes are formed by the solute and the solvent, and that the association of the solvent is not changed by introduction of the solute. The association constants calculated in this manner vary with the solute and are, in general, lower than those found by other methods. Friend (1933) gives association factors of water found by introducing various substances as follows (from Oddo): phenol, 1.18; p-toluidine, 2.00; chloracetic acid, 1.40; cyamide, 1.64; acetic acid, 1.73. If these constants were accurate, there would be a large amount of monohydrol in water at 0°C. However, other considerations indicate that these values are too low, and the value generally assumed is considerably higher. For example, the equation of Walden (see Friend, 1933) indicates that phenol, assumed to be non-associated in this calculation, is associated to a considerable degree.

MAGNETIZATION OF WATER

It seems unnecessary to mention all of the numerous papers dealing with the association of water written since the Symposium of the Faraday Society in 1910; only those which bring forward points of special interest, such as those of Duclaux, will be mentioned. Piccard (1912) was one of the first to follow changes in the magnetization coefficient of water with temperature. These changes he explained by assuming that water at ordinary temperatures is a mixture of two substances.

The diamagnetism of water at different temperatures has received very careful study recently by Wills and Boeker (1932) who used a specially devised manometric balance of great sensitivity. Piccard had

found that the specific susceptibility of water increases with temperature, while the results of others indicate exactly the reverse. It is probable that these discrepancies are due in part to the *thermal history* of the water samples investigated. Wills and Boeker give two curves, one of which, obtained from water which had stood for several days in contact with helium gas, is a true equilibrium curve, indicating an increase of susceptibility with temperature. The other curve, indicating a decrease in susceptibility with rising temperature, was obtained from water which had been boiled vigorously for fifteen minutes immediately before the experiments. The authors state that the difference between the curves cannot be ascribed to errors of observation or to peculiarities of the apparatus, but might be explained "on the assumption that polymerization changes in water produced by variation in temperature required for their completion a considerable time." If this hypothesis is true, it affords valuable support to our assumption that water from steam and from ice possess different degrees of polymerization for a limited time. Certainly if the mere thermal history influences the degree of polymerization, an actual change of state, from vapor on the one hand and ice on the other, should have even more pronounced influence on the resulting water. As will be shown later (H. T. Barnes, 1929) the ice-forming power of water at low temperatures indicates a considerable lag in the association equilibrium. In a more recent paper Boeker (1933) has repeated these experiments, using several non-associated liquids. In none of the experiments with non-associated liquids did he obtain a hysteresis effect which might be due to the thermal history of the liquid. This strongly supports the theory that the equilibrium ratio of the water polymers is

not reached instantaneously, and it shows that the hysteresis effect is not due to a defect in the apparatus used. On the other hand a hysteresis effect is not described by Cabrera and Fahlenbrach (1933) in their paper on the variation of the diamagnetic constant of water with temperature. The work of Wills and Boeker helps to explain Hegarty and Rahn's (1934) discovery that recently condensed water retards bacterial growth.

PRESSURE AND COMPRESSIBILITY STUDIES

The important studies of Bridgman from 1912 onwards on various modifications of ice under pressure have been succinctly summarized by Honigsmann (1932). As Honigsmann points out, the melting curves of the special varieties of ice, other than Ice I, do not, on the basis of the Tammann interpretation, necessarily involve great changes in molecular complexity. Bridgman's work indicates that -22°C . is the minimum freezing point of water under any equilibrium conditions, but Gortner (1930) reports the presence of liquid bound water in colloids and tissues far below this critical temperature (explained by the capillarity conditions).

Bridgman showed that at 2500 atmospheres pressure the density-temperature curve of water has no maximum, but is a straight line, as for normal liquids at atmospheric pressure. This is ascribed to the destruction of the polymers at very high pressures. H. T. Barnes (1928, p. 26) states that the temperature of maximum density recedes towards zero at a rate of 0.025°C . per atmosphere. This lack of a maximum density is comparable to that obtained with concentrated salt solutions (Bousfield and Lowry, citations above). In this connection it might be mentioned that sea water shows no maximum density, and it would be very interesting to re-examine other properties of sea water in

view of the influence of salts on the degree of polymerization. In this connection it is deplorable to note that oceanographers ignore the polymerization factor in sea water.

It is known that as pressure is increased the minimum of compressibility of water at 50°C . is not shifted toward lower temperatures but is wiped out where it stands at 50°C . This is not consistent with the binary theory of Röntgen and Sutherland, but is consistent with the ternary theory of Callendar and Bousfield and Lowry. This theory assumes that above 50°C . monohydrol (possessing, like trihydrol, a greater bulk than dihydrol) becomes important in concentration.

The ternary theory received further support in the careful compressibility measurements on solutions of urethane made by Richards and Palitzsch (1919) by means of a glass piezometer. Urethane is very soluble and does not dissociate or associate, and is therefore an ideal substance for this work. It is well known that all aqueous solutions show a marked diminution in compressibility with increasing concentration, even when the dissolved substance is more compressible than pure water. In spite of the fact that alcohol has twice the compressibility of water, the addition of less than 20 per cent alcohol to water at room temperature diminishes the compressibility of the solution. This is probably caused by the destruction of the more compressible trihydrol molecules by the alcohol (as van Laar (1899) suggested, but cf. Bancroft and Gould (1934)).

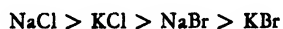
The compressibilities of urethane solutions were measured at constant temperature (20°C .) over a pressure range of 100 to 300 megabars. With increasing concentrations of urethane the compressibility decreased rapidly from 43.25×10^{-8} (the compressibility of pure water) to 38.91

$\times 10^{-6}$ at 34 grams per 100 grams of water. From this point the compressibility increased at first slowly and then more rapidly; at the highest concentration measured (127.3 grams per 100 grams of water) the compressibility was 40.80×10^{-6} . The conclusion is that the effect of dissolving anything in water is to dissociate part of the trihydrol present, thus diminishing the compressibility. The rise in the compressibility of urethane solutions with increasing concentration above 34 grams per 100 cc. can be ascribed to the increasing concentration of monohydrol.

Measurements of solution volume also indicated that urethane causes the breaking down of trihydrol into dihydrol, and this effect diminishes as the concentration of trihydrol is decreased. The surface tension shows a very marked falling off for low concentrations, but in 40 per cent solutions (from which the trihydrol has been eliminated) the surface tension decreases far less rapidly. The viscosity rises rapidly with concentration, showing that the viscous urethane more than compensates for the diminished amount of trihydrol. In brief, the results of Richards and Palitzsch are precisely what one would expect if water contained an appreciable amount of trihydrol in dilute solutions and an appreciable amount of monohydrol in concentrated solutions (as Armstrong maintained), dihydrol being present under all conditions. This work was extended to aqueous solutions of urethane, ether, alcohol, and methyl acetate by Richards and Chadwell (1925). On the basis of solution volumes they obtained percentages for polyhydrol in water which agree rather closely with those of Whiting and Sutherland, but which were somewhat lower than those of van Laar (1899). Moreover, this interpretation is supported by the recent paper of Freyer (1931) on the physical properties of liquids as revealed

by compressibility and the velocity of sound in solutions of alkali halides.

Freyer considers the possibility that the presence of ions may change the condition of aggregation of the water molecules, *i.e.*, may shift the trihydrol-dihydrol-monohydrol equilibria. He suggests that any effect of this kind would actually be brought about as a result of hydration. For a given concentration those solutions with the most highly hydrated solutes will have a lower compressibility, and the contraction of water is inversely proportional to the mean radii of the ions producing it. This, of course, follows from the greater intensity of the electric field about the ions of low atomic weight and small radii, which results in a greater attraction of the water dipoles for the ions—the so-called *electroconstriction*. It is known that a decrease in compressibility is accompanied by an increase in the velocity of sound through water and that an increase in density accompanies a decrease in velocity. In the case of the most important salt, NaCl, the compressibility greatly predominates, and the velocity of sound through NaCl solutions increases rapidly with concentration. This predominance decreases in the following order:

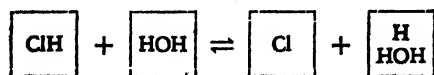


It would be of interest to reconsider the velocity of sound in sea water and body fluids on this basis.

ACTIVITY IN RELATION TO HYDROGEN IONS

The chemical activity of water is considered at some length by Rice (1923), although not in connection with the problem of polymerization. Rice points out that stoichiometrically neutral water may not be neutral catalytically. Water is considered neutral when the total hydrogen and hydroxyl ion concentration are

equal and since the unhydrated ions are present in very minute amounts the concentration of hydrated ions will be equal at this point. But the concentration of unhydrated ions will not be equal for the affinity of H^+ for water is greater than the affinity of the OH ion; thus a stoichiometrically neutral solution will be "alkaline" catalytically, for the unhydrated H ion is assumed to be the active form. Making the solution acid stoichiometrically (pH 5) makes the concentration of the two unhydrated ions equal and the solution will have a *minimum catalytic activity* at pH 5. That the unhydrated H ion is the active catalyst (as first proposed by Lapworth) is suggested by the fact that H ion in some instances catalyses faster in alcohol than in water and by the stability of acetates between pH 4.7 and 5.1, etc. Rice points out that although many H ion catalyzed reactions have a value of approximately 20,000 calories for the quantity Q in the Arrhenius equation, we cannot calculate the change in concentration of the unhydrated H ion with temperature for we do not know the concentration of simple water molecules present nor the number of water molecules combined with the hydrated H ion. Further investigation is needed to show whether the degree of polymerization of water will effect the concentration of the active unhydrated H ions. Moreover, the unhydrated H ion may be an abstraction, for according to Lowry (1930, p. 964), the H ion is unknown except as an internal parasite in a water molecule. The free H ion is a naked proton and has only a transient existence as a positive ray in a vacuum tube. The usual equation $HCl \rightleftharpoons H:Cl$ should represent a transference of a parasite from one host to the other.



Moreover, as Prof. H. S. Harned has informed us, the reaction $H^+ + H_2O = H_3O^+$ has a free energy of -300,000 calories (approx.), and therefore, the concentration of free proton would be too small to be catalytically significant.

Gortner, Hoffman, and Sinclair (1928) consider the possibility that one should not ignore the denominator, as is usually done, in the equation for the dissociation of water into H and OH ions, for they suggest that possibly only monohydrol dissociates, and of course, its concentration is relatively small at biological temperatures. The equation they suggest is



If only a small amount of monohydrol is present, there might be an appreciable change in its concentration due to dissociation, in which case the concentration of H_2O could not be disregarded as negligible in calculations of K_w . However, they consider that there is no means of determining the relative proportions of water molecules in their different degrees of polymerization. It is probable that the pH change of pure water with temperature is conditioned by the temperature shift in the polymer ratio.

Pennycuik (1928) states that the ions of water can not be dissociated from the contiguous water molecules which brought them into existence, or in other words that these ions are always hydrated. In the same way the hydrogen ions of acid solutions are always directly associated with the surrounding water molecules. A hydrogen ion would be more correctly written as $[H(OH)H(OH)H]^+$ and a hydroxyl ion as $[(OH)H(OH)H(OH)]^-$, where the ionic groups are continually increasing or decreasing the amount of water with which they are associated. Now, in these hydrated ions it is impossible to say which of the removable hydrogen nuclei (four in the above formula) or which of the removable hydroxyl radicals (two in the above formula) represents the hydrogen or hydroxyl ion. We must assume the whole hydrate to carry the positive or negative charge. It will be noticed that

while other ions, such as Na^+ or Ca^{++} (undoubtedly hydrated), have an individual existence in aqueous systems, the hydrogen and hydroxyl ions in such systems do not exist as unchanging individuals, but, owing to the nature of the solvent, the particular nucleus which may be arbitrarily taken as representing a hydrogen ion at any one instant may exist at another as part of a water molecule, the liberated hydrogen nucleus becoming the hydrogen ion. Perhaps we have here the most common example of tautomeric hydrogen. The catalytic effect of the hydrogen ion on hydrolyses in general is probably intimately connected with this tautomeric change; for a water molecule undergoing such a change would be in a peculiarly unstable (loosened) condition, and as such would be particularly open to internal rupture.

This unique position of the H ion in water led Bernal and Fowler (1933) to propose a new theory of the structure of water (see below). They recognize that the H ion is not a naked proton but must be firmly attached to at least one water molecule as $(\text{OH}_2)^+$, the oxonium ion, in which the extra proton is attached near one of the two vacant tetrahedral positions among the electron orbits, the whole structure being similar to the ammonia molecule, NH_3 . According to quantum mechanics an $(\text{OH}_2)^+$ ion in sufficiently close contact with a water molecule (OH_2) need not retain its extra proton but can transfer it to the other molecule. Thus the proton jumps (in the sense of Hückel) to and fro from one to the other when the configuration of the two molecules is favorable and this leads to a large extra drift down the field (the unexplained mobility of the H ion). Apparently Latimer and Rodebush (1920, p. 1432) were the first to suggest this explanation.

INFRA-RED ABSORPTION

Mention must be made of the infra-red absorption of ice described by Plyler (1924). In this study plane polarized light was allowed to fall upon the ice crystal, and the percentage transmission was determined. Plyler found that it was impossible to obtain clear ice by freezing distilled water between glass plates, but very clear pieces of ice were obtained by cutting sections out of a block of artificial commercial ice. It was necessary in this work to use single crystals, because the spectral transmission is less when the absorbing direction is parallel than when it is perpendicular to the direction of the light. Large crystals were obtained by keeping commercial ice slightly below the freezing point for two months. This crystal growth has not been explained but Altberg and Troschin (1931) have found single crystals half a meter in size in mountain caverns. The location of the absorption bands for ice (for the extraordinary ray) were 0.81, 0.92, 1.06, 1.29 μ and for water at 0°C., 0.74, 0.84, 0.98, 1.21 μ . Plyler shows that the values for water vapor, water at 100°C. and 0°C., and ice give a smooth curve when plotted against Sutherland's estimated percentages of trihydrol at these temperatures. The increasing concentration of trihydrol shifts the bands toward the longer wave lengths.

Collins (1925) made a special study of changes in the infra-red absorption spectrum of liquid water between 0°C. and 95°C. (Table 5). As the temperature was increased he found a shift toward shorter wave lengths and a marked increase in the magnitude of maximum absorption for bands at 0.77, 0.98, and 1.21 μ . Collins explains these changes qualitatively on the hypothesis that water is a mixture of at least two kinds of molecules whose relative amounts change with

temperature. Neglecting the effect of the hydrol (a questionable procedure) he suggests that the bands in the spectrum of dihydrol have slightly shorter wave lengths than those of trihydrol. A comparison of the spectra of water vapor, water, and ice indicates that the bands of dihydrol near 1.45 and 1.96μ are not so intensive as corresponding bands of trihydrol. The intensity of these bands increases with increasing complexity of the molecule, while in bands at shorter wave lengths the reverse is true. Splitting of trihydrol into $1\frac{1}{2}$ molecules of dihydrol might explain the increase in the active absorption bands of dihydrol. Plyler and Craven (1934) announce new bands at 3.30μ , 5.56μ and 5.83μ . They consider that the bands are made up of two or more components which vary in intensity with

DEVELOPMENTS IN THE THEORY OF WATER STRUCTURE, 1926-1929

Tammann (1926) considered the molecular complexity of water in detail based on the presence of a type of molecule of large volume and possessing the reticular structure of Ice I. He had previously (Tammann, 1910) suggested that ice exists in several forms which fall into two groups: (a) lighter than liquid water and (b) heavier than liquid water. Ice belonging to the first group separates only from water rich in polymolecules while ice of the second group separates only from water containing an abundance of simple molecules. In the later paper (1926) he calculates the proportions of Ice I in liquid water (cf. Table 1). On the assumption that molecules of the four kinds

TABLE 5
Location of Maximum Infrared Absorption Bands in Liquid Water (Collins, 1925)

At $0^{\circ}\text{C}.$775		.985	1.21	1.45	1.96 μ
At 95°74	.845	.97	1.17	1.43	1.94 μ

temperature. Ellis and Sorge (1934) report that water samples from condensed steam and fresh ice have similar infra-red bands. However, ice (almost 100 per cent trihydrol) and water (37 per cent trihydrol) have similar bands with differences in the second decimal place only, so that a 10 per cent polymer difference would not be clearly indicated by their method. Other physical tests, on the contrary, demonstrate differences in ice and steam water (see below) (T. C. Barnes, 1934b).

Ellis (1931) finds infra-red absorption bands in the liquid and solid states which are absent in the vapor and his results support the theory of Kinsey and Sponsler (1933) that the units H_2O_2 and H are present in liquid water linked in groups or a lattice-work.

of ice are present in water there are four types of water molecules polymerized or isomeric with each other, but the molecules resembling Ice I are the only ones that can be clearly recognized. At high temperatures and low pressures water probably contains molecules of $(\text{H}_2\text{O})_2$ which were recognized by Nernst. The determination of the concentrations of molecules of type 1 permits the thermodynamical calculation on their molecular weights— $(\text{H}_2\text{O})_9$ in case these molecules dissociate into $9\text{H}_2\text{O}$, and $(\text{H}_2\text{O})_8$ in case they dissociate into $2(\text{H}_2\text{O})_4$. His consideration of the temperature-volume curve of water is similar to Sutherland's, but Sutherland's paper came to his attention after his own calculations had been made.

Baker (1927) reports some interesting experiments on molecular association, showing that association like dissociation of molecules takes place much more slowly for liquids than for gases. In liquids the equilibrium can be easily disturbed by even a slight change in temperature and the return to normal conditions takes a long time, sometimes even months. The presence of a catalyst like charcoal increases this lag in the equilibrium. Thus a water sample having a vapor pressure of 2.5 mm. was heated for 48 hours at 80°, and a day later its vapor pressure was 4.3 mm. West and Menzies (1929) find a slight change in the vapor pressure of water after thermal treatment even in the absence of a catalyst but Wright and Menzies (1930) do not observe this effect in acetic acid. The vapor pressure, however, is not always a significant indicator of polymerization but might show a difference in monohydrol (see below).

A new method of separating polymers in liquids has been proposed by Berkeley (1927) who believes that the separation of constituents of a liquid might take place in a centrifuge tube rotated at a high velocity. Isotopes might also be segregated by this method. It would be of great interest if separation of water polymers could be partially effected in this way although Longinescu (1929) points out that Svedberg's ultra-centrifuge (42,000 × gravity) will not separate molecules unless the difference in molecular weight is some ten thousand fold. Perhaps the new centrifuges of Svedberg (1934) and Beams, Pickels and Wood (1934) will ultimately develop fields of sufficient magnitude.

H. T. Barnes (1926) discusses colloidal forms of water in Alexander's *Colloid Chemistry*. We have already seen that ice molecules in water influence the shape of the density, specific heat, and viscosity curves with temperature. He points out that the beginning of the true colloidal form of water is the formation of trihydrol from dihydrol at temperatures below 60°C. The final ice molecule, trihydrol, is devoid of all crystal form above 0°C. and remains invisible until the freezing point is reached. At this temperature it becomes sufficiently concentrated and the molecular groups become of sufficient size with relation to the remaining dihydrol molecules to affect light reflected from the depths of the water, thereby producing a very delicate change of hue. Also the

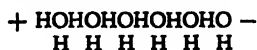
vivid color of iceberg ice and of water from glaciers is caused by the molecular structure. Since the freezing process eliminates all foreign matter from clear ice this scattering of light cannot be due to dust particles. H. T. Barnes also states that freshly formed ice is in the nature of a great clot which undergoes structural alterations. The structure of ice depends upon its rate of formation; ice formed slowly by natural means is composed of large crystals, but ice formed rapidly from slightly super-cooled water is composed of fine crystals. The best biological results are obtained with large crystal ice.

It is interesting to note that the moisture content of organic liquids results in the appearance of colloidal particles (colloidal water and ice in cooled chloroform); but as H. T. Barnes points out we are only on the threshold of our knowledge of the action of colloidal water and "*the influence of these liquid aggregates on chemical action has been completely overlooked in the past but may be the real seat of the chemical activity of water.*" In H. T. Barnes' book *Ice Engineering* (1928), half of which is devoted to the pure physics of ice and water, the following important statement occurs: "It is highly probable that perfectly pure dihydrol would be chemically inert, . . . if we could find a way to destroy trihydrol molecules in water that fluid would no longer be useful to living organisms nor could it ever freeze."

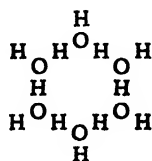
This theory that the activity of water is due to the trihydrol is supported by the effect of ice water on *Spirogyra* and *Euglena*. As has been discussed above, Armstrong takes the opposite view, that the water monads are more active, but according to Armstrong their activity may express itself in the *dehydrolating* and consequent inactivating of dissolved molecules of other substances, which is not incompatible with the hypothesis that water poor in

trihydrol but rich in monohydrol would not be as active as ice water and this might explain the discovery of Hegarty and Rahn (1934) that recently condensed water retards the growth of bacteria. It is probable that the effect of water polymers will be largely conditioned by the type of chemical reaction influenced and the nature of the solute molecules.

Pennycuik (1928) states that the stable polyhydrol of water is not di- or tri- but is hexahydrol. The water molecule is tetrahedral in structure and has a strong tendency to form chains of varying length. Due to the angles of the tetrahedron, a six membered chain may become closed. Such a ring bears a strong resemblance to the inactive benzene ring, and it would be much more stable than any of the lower polymers. One might consider water to be a mixture of relatively stable hexahydrol rings and of lower unstable polymers of continually changing size. He states that "the unique properties of water—high dielectric constant, the solvent activity, remarkable and general catalytic activity, and even the physiological importance must finally be traced to the structure of the individual molecule itself—in most respects unique." He points out that the molecule is polar, i.e., unsymmetrical and a tetrahedron where the electrons are in pairs at the corners (Fig. 3), due to the tetrahedral structure of the saturated oxygen atom. Hence water can attach itself to other molecules either through its own negative pairs or through its own positive hydrogen nuclei, which accounts for the positive and negative affinity of the water molecule. The various properties of water can be explained on the assumption that the molecules are held together solely through the attractions between the H nuclei and the O lone electron pairs. Thus polar chains are formed.



which may close into the benzene ring structure



in harmony with the hexagonal structure of ice.

Pennycuik regards association in the liquid state as a "perfectly general" phenomenon and considers

that the equation of state of van der Waals can be deduced equally well by substituting the idea of molecular association for the conception of internal pressure. He cannot accept the view that water is a mixture of mono-, di- and tri-hydrol, each having a statistical average existence because such a liquid would behave as a normal quasi-associated system; rather he considers water as a mixture of relatively stable compound molecules of benzene ring structure in a normal solvent. Stewart (1931), Bernal and Fowler (1933), and Kinsey and Sponsler (1933) also favor this notion of a molecular group and not a mixture of three molecular types but Rao (1934, p. 498) shows that water is a ternary system as revealed by Raman spectra.

Longinescu (1929) has recently published a stimulating paper on the nature of molecular association, which concept he attributes to Louis Henry. Longinescu points out that in spite of all attempts to describe water as a mixture of simple, double and triple molecules, etc., not a single type of these molecules has been isolated. To explain this "failure" (as he terms it) the hypothesis was invented that the associated molecules are in unstable equilibrium so that they dissociate and come together again with great rapidity. In collaboration with Chaborski he puts forward an alternative hypothesis that molecular "association" is in reality a phenomenon of molecular *concentration*. In place of the idea of molecular complexity they introduce the notion of molecular accumulation. Thus water which shows the highest degree of molecular association has the greatest molar concentration and hence the highest degree of accumulation. Liquids, like gases, consist solely of simple molecules and the greater a liquid is "associated," the greater the number of these molecules in equal volumes. In numerous cases the degree of association is one-tenth of the molar concentration. The author does not attempt a detailed refutation of the numerous lines of evidence for the trihydrol hypothesis.

LAG IN ATTAINMENT OF EQUILIBRIUM OF POLYMERS

More recent developments of the trihydrol hypothesis are reported by H. T. Barnes (1929) concerning the ice-forming power of water. He shows that water may be exhausted of its ice-forming power by experimental means (Fig. 1). For instance, water was cooled in a tank at ten to fifteen degrees below freezing (air temp.). After the expiration of definite

time periods the ice was removed and measured, and the water was allowed to form fresh ice. In a typical experiment under given conditions the first half hour yielded a full pail of ice. However, another full pail of ice was not formed for another full hour, and still another two hours were required for the formation of the third full pail of ice. For four hours afterwards there was no ice

tion, especially at low temperatures. When the exhausted water is rewarmed to 20° and then cooled, it will freeze readily, indicating that the establishment of polymerization equilibrium is more rapid at higher temperatures.

Wills and Boeker (1932) (see above) detect a polymer lag with a diamagnetic method. Menzies (1934) is skeptical of the physical evidence, such as that of

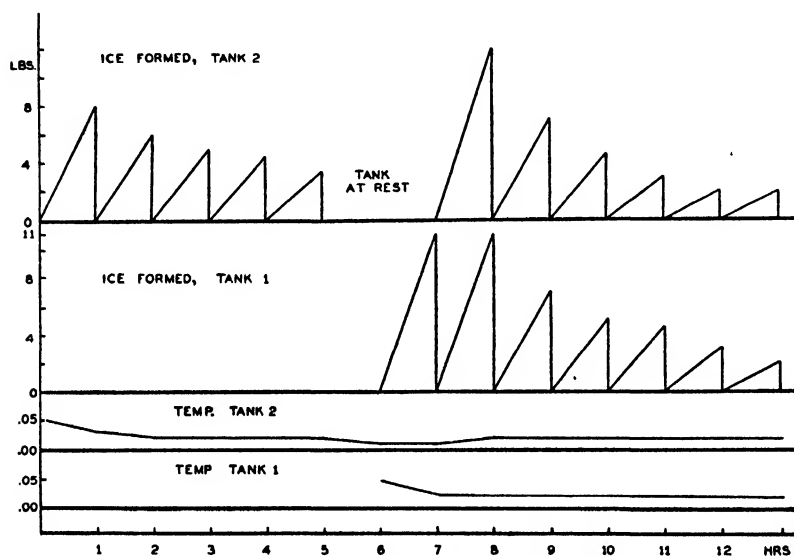


FIG. 1. EXHAUSTION OF THE ICE-FORMING POWER OF WATER

(From unpublished data of H. T. Barnes, cf. H. T. Barnes, 1929.)

The graphs show the amount of ice formed per hour in large tanks. The ice was removed and measured each hour and the remaining water allowed to form new ice. Stirrers in the water and electric fans in the air above were running continuously except for the fifth and sixth hour when tank 2 was at rest. The interval permitted enough "trihydrol" to reform so that this partially exhausted water had recovered during the seventh hour as judged by the quantity of ice formed which was the same as in the control tank 1, started at the beginning of the sixth hour. These experiments can be interpreted on the assumption that at 0° two hours is required for the attainment of the equilibrium between polymers.

produced; the ice-forming power of the water had been temporarily exhausted. This interesting result can be explained on the colloidal theory; a nucleus is required for the colloidal ice mass, and after removal of these nuclei the formation of further ice is rendered difficult. This passive state of water can be explained, also, on the ground that time is required for restoration of the trihydrol in solu-

Barker (1927) (see below) but suggests that the biological method may be more sensitive.

RECENT WORK ON ASSOCIATION

Stakhorski (1930) has recently applied the equation of Kordes' Law to water and its mixtures with another substance. He uses an equation of the following form

$$X = [M_b \cdot a (T - T_i) \cdot T_b / M_b (T_b - T_i) T_i]$$

in which X is the association factor, a and b are concentrations of the two components A and B and T_a , T_b , and T_e are the melting points of A and B and the eutectic mixture. He concludes that the application of Kordes' Law confirms the theory that water is a typical associated compound.

Stewart (1931) has considered the nature of the molecular association of water as revealed by his x-ray diffraction studies. He gives the x-ray diffraction intensity angle distribution for water and its variation for temperatures of 2° and 98°. Two important periodicities are established at 3.24 and 2.11 Å. U. and a third at 1.13 Å. U. The first one decreases with temperature and the second increases. Stewart suggests in his discussion of molecular polymerization that the description of association involving complexes of two or three molecules should be abandoned in favor of the molecular group conception (cf. Bernal and Fowler, 1933). According to Stewart the conception of molecular complexes explains neither the existence of the x-ray periodicities nor their change with temperature. The groups of water molecules postulated by Stewart (cybotactic condition) may contain hundreds and perhaps thousands of molecules in each, having a temporary existence as individuals with ill-defined boundaries and possessing an optimum size and an internal regularity determined by the temperature and molecular forces. A detailed description of the molecular arrangement in water from x-ray data is not at present possible, yet it simulates the crystal structure.

An entirely new aspect of the polymerization problem is considered in the recent paper of Plotnikov and Nishigishi (1931) dealing with the rhythmicity of the trihydrol equilibrium. When the longitudinal scattering of a carbon arc

passed through an alcohol solution was photographed at minute intervals, a periodic fluctuation of the amount of scattering was observed. The same effect was obtained with other substances at various temperatures. In aqueous solutions this rhythmicity can be interpreted as a steady interchange between different sizes of the molecular complexes of water, a fluctuation around the point of chemical equilibrium. Large sugar molecules increase the scattering and decrease the amplitude of the water fluctuations. Plotnikov suggests that this phenomenon is one of a general class of periodic processes which might be of importance for biology. It is concluded that the scattering effect is a very sensitive method for studying the properties of polymolecular complexes. These experiments support our hypothesis that the association equilibrium is not attained instantly as many physical chemists believe from an *a priori* line of reasoning.

Bernal and Fowler (1933) have recently published an important paper giving a new theory of water and ionic solution with particular reference to H and OH ions. Their consideration of the spectroscopic molecular model of H₂O, of the crystal structure of ice and the density of water lead them to propose an irregular 4-coordinated structure for water which accounts for the positions of the maxima of the x-ray diffraction curves. The structure of water has three forms, i.e. Water I: ice-tridymite-like (4-conditioned) at temperatures below 4°; Water II: quartz-like (4-conditioned) in the range 4°–200°C.; and Water III: ammonia-like, close-packed occurring in the range 200–340°C. Water I (Fig. 2) is the fundamental structure which is distorted by higher temperatures, the aggregate of greatest biological interest being the quartz type (Fig. 2) since it is the form over the physiological temperature range.

The arrangement of an H_2O molecule of 1.4 Å radius surrounded by four others in a more or less regular tetrahedron is that found in ice and follows from the quasi-tetrahedral angle of the H_2O molecule (cf. Debye (1929) for the structure of monohydrol). The proton near the surface of one molecule lies opposite the empty place in a neighboring molecule, i.e., in a place where the proton would be in such a molecule as CH_4 . In silica, SiO_2 , where a similar four-fold coördination holds, there are three main crystalline forms: cristabolite, tridymite, and quartz.

forces of cohesion of the liquid. The break down of the empty ice-like structure is a decrease in volume to water II, followed by an increase of a more normal kind to water III, where the thermal agitation more than compensates for the geometrical contraction of the transition from the quartz-like to the close packed structures. According to these authors trihydrol, dihydrol and hydrol have no direct structural analogy to water I, II and III, but the latter explain, by means of the geometrical internal structure of the liquid, physical properties which the

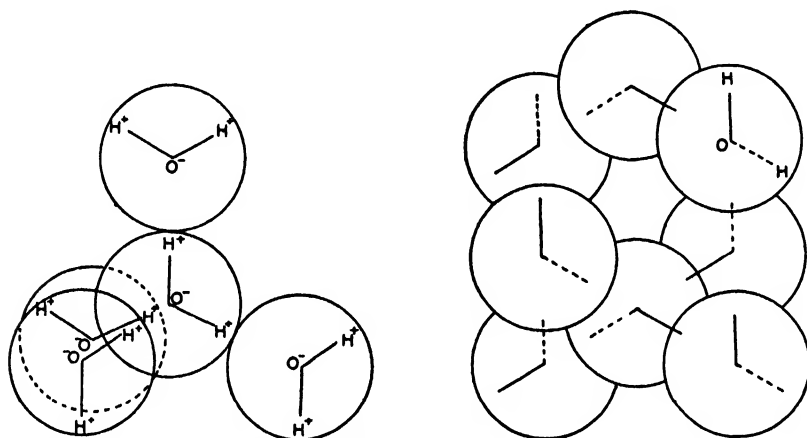


FIG. 2. MOLECULAR STRUCTURE OF WATER PROPOSED BY BERNAL AND FOWLER (1933)

At left the ice-tridymite-like water aggregate present at temperatures below 4°C . At right the quartz-like water form existing in the temperature range 4 – 200°C . This would be the typical arrangement in biological fluids. The OH directions pointing upwards are shown ———, downwards - - - - -

Of these the tridymite corresponds to ice, and water is simply an irregular version of this. The three forms pass continuously into each other with change of temperature. Like Stewart (1931), Bernal and Fowler state that there is no question of a mixture of volumes with different structure; at all temperatures water is homogeneous, but the average mutual arrangements of the molecules resemble water I, II and III in more or less degree. The sequence is one of increasing rotatory and translatory molecular movement, and the consequent diminution of the dipole

former attempted to explain in terms of hypothetical molecules. On the other hand the recent considerations of Bancroft and Gould (1924) are based on the hydrol-dihydrol-trihydrol conception.

Bernal and Fowler introduce a new conception of "structural temperature" based on the changes in the structure of water caused by ions, which they believe may prove to be important in many physico-chemical fields, particularly where colloids are involved, and in bio-chemistry. In dilute solutions of strong electrolytes the "structural temperature" is that tem-

perature at which pure water would have effectively the same inner structure as the given solution. The ions loosen or tighten the water molecules depending on their ionic radii and charge. This may explain the antagonistic action of ions such as Ca^{++} and K^+ , the first lowering, the second raising the structural temperature.

The most recent speculations concerning the molecular structure of ice and liquid water are those of Kinsey and Sponsler (1933) derived from an ice crystal lattice which is new so far as the H ion positions are concerned and is based on the O positions previously determined by W. H. Barnes (1929). The structure provides dihydrol as the polymer occurring in both ice and water. The authors postulate a stable H_3O_2 ion in the crystal and in clusters of dihydrol occurring in liquid water, an assumption which allows a qualitative explanation of many of the abnormal properties of water and ice. Their statement that liquid water is not composed of mono-, di- and tri- hydrol is not supported by the historical evidence (*vide supra*). However, they appeal to the fact that the only lattice which has been proposed for ice is ionic and does not contain a complex unit of any sort. They attempt to reconcile the ionic picture of ice with the notion of polymers by postulating the alternate spacing (Fig. 3) of an H cation and a complex double pyramidal anion H_3O_2 . The whole lattice is a cluster of linear chains of dipole dihydrol units which melt by the destruction of the lattice brought about by a too close approach of the singular H ion (Fig. 3) and the H_3O_2 groups. The result is a liquid which is a mixture of mono- and di- hydrol in temperate equilibrium. In water, clusters of variable size of the two types of molecule are the mobile units. The x-ray diffraction phenomena point to the exist-

ence of a kind of orderly clustering which may follow the crystalline arrangement.

Bancroft and Gould (1934) have recently published a splendid paper on the Hof-

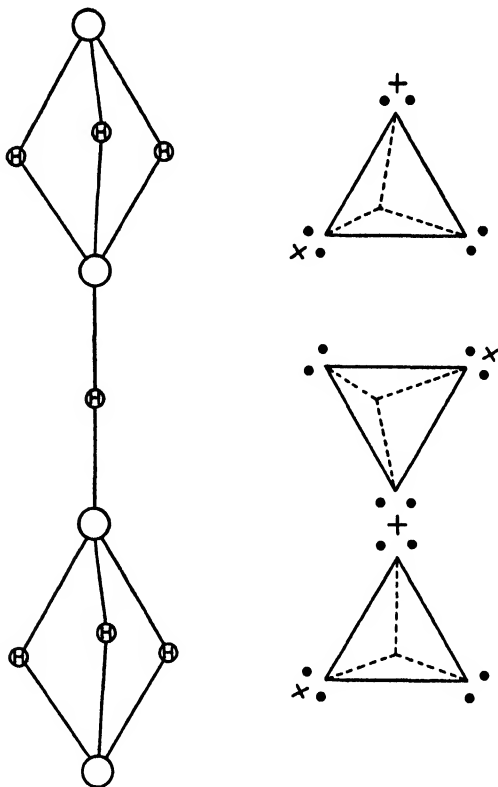


FIG. 3. MOLECULAR STRUCTURE OF WATER

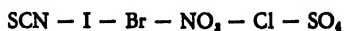
At left the molecular structure of water according to Kinsey and Sponsler (1933) based on the ice lattice of W. H. Barnes (1929). The structure provides dihydrol as the polymer occurring in both ice and water. The pyramidal anion H_3O_2 is alternately spaced with the H ion.

At right the simple water molecule as proposed by Pennycuik (1928) based on the tetrahedral structure of the saturated oxygen atom (the O nucleus with its two helium electrons is omitted). The two H nuclei and the two O lone pairs of electrons are the points of attachment (lower figure) in the formation of chains of water molecules which may close to form a hexahydrol resembling a benzene ring structure (see text).

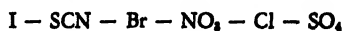
meister series of anions with specific reference to their effect on the water equilibrium of mono-, di- and tri- hydrol. They point out that liquid water is recognized as being more or less polymerized, but

little use is made of this except to account for the temperature of maximum density of water and for its not boiling at 80-193°K. as calculated by van't Hoff, Walden, Tammann and Sidgwick. In many thermodynamical reasonings the assumption is made tacitly that the degree of polymerization does not change and very few people are interested in the probability of the different forms of liquid water having different properties, yet changes in the structure of water may be very important in such salt solutions as the Hofmeister series. The lyotropic series of chloride, bromide, iodide, etc., is found to hold for true and for colloidal solutions. In true solutions the series holds for reaction velocity experiments (neutral salt effect), electromotive forces, boiling points and displacements of the temperature of maximum density.

The series cannot be entirely due to hydration of ions because the boiling points are more abnormal than the freezing points. Many people have suggested an increased dissociation of water, but no one has maintained it seriously for any length of time. For cases in which one can eliminate adsorption the Hofmeister series is due exclusively to a change in the water equilibrium. When adsorption is selective (as with albumin) a common order is:



but where adsorption is negligible the series may become:



The authors make a number of assumptions to explain the shift in the water equilibrium: (1) chloride, bromide, thiocyanate and iodide tend to change dihydrol into monohydrol and have no special effect on trihydrol beyond that which is a necessary consequence of the displace-

ment of the equilibrium between dihydrol and monohydrol. The order of increasing effectiveness is chloride, bromide, thiocyanate and iodide. (2) The nitrate ion tends to convert trihydrol into dihydrol and dihydrol into monohydrol. The amount of monohydrol is less with nitrate ion than with the chloride ion. (3) The sulphate ion tends to convert trihydrol and monohydrol into dihydrol. (4) The electrolytic solution pressure of H is greater in dihydrol than in monohydrol and that of O is less. These assumptions are based in part on the following considerations. Iodides have the highest boiling point and then come thiocyanates, bromides and chlorides. If iodides are the most effective in converting dihydrol into monohydrol then they are more soluble in monohydrol than in dihydrol and are consequently lowering the vapor pressure of the more volatile constituent, therefore the boiling point is abnormally large. Also, iodide lowers the maximum density of H₂O more than bromide and bromide more than chloride. Unfortunately nitrate is more effective than iodide and sulphate more than nitrate. Accordingly the additional assumptions are made that nitrate tends to convert trihydrol into dihydrol and the dihydrol into monohydrol and that sulphate tends to convert trihydrol and monohydrol into dihydrol. The addition of NaCl, NaBr or NaI to a solution of an acid increases the hydrogen ion concentration which necessitates the assumption that the electrolytic solution pressure of hydrogen is greater in dihydrol than in monohydrol (and that of oxygen is less).

In contrast to van Laar (1899) they postulate that alcohol increases the trihydrol concentration since it raises the point of maximum density, and since alcohol will bring back the fluorescence to a too concentrated fluorescent solution, they

consider that trihydrol has a specific effect in promoting fluorescence. Here we see that one of the "closed molecules" of Armstrong may be quite active as the *Spirogyra* and *Euglena* experiments suggest (see below).

Finally the Raman spectrum of water may be considered as a possible indication of the structure of water but it must be remembered that "the effect of the physical state is small in most cases, liquid water, ice and water of crystallization, for example, showing almost the same Raman spectra" (cf. *Nature*, vol. 131, 1933, pp. 263-265). However, Specchia (1930) has examined the Raman spectrum of water at various temperatures (17°, 41°, 80° and 91°) as a possible means for studying changes in the polymerization of water. A slight displacement of the bands was noted, e.g., the maximum 4176 Å. U. at 17° is displaced to 4188 Å. U. at 91°.

Brunetti and Ollano (1930) studied the Raman spectrum of water as affected by solutes, and they find differences in the intensities of the bands produced by presence of salts. It is interesting to note that the nitrate anion has a contrary effect to that of the chloride anion which may turn out to be a lyotropic effect (cf. Bancroft and Gould, 1934). According to Bernal and Fowler (1933) the Raman spectrum changes in aqueous solutions indicate distortion of the water structure by the solute. Rank (1933) has recently discussed the Raman spectrum of water vapor. According to Rao (1933, 1934) the Raman component in water vapor may be attributed to the single water molecules and the two components of the ice spectrum indicate double and triple molecules (trihydrol). In water at different temperatures all the three components are found with varying relative intensities and from them Rao attempts a calculation of the relative proportion of water molecules (cf. Table 1) at different temperatures. He considers this method more direct than that of Sutherland (1900). He finds a maximum number of double molecules at 4° which perhaps explains the maximum density at this temperature. His percentages of trihydrol at various temperatures agree well with the numerous other determinations (Table 1) but his proportions are somewhat low; for example at 4° he finds only 21 per cent trihydrol as compared to Sutherland's 37.5 per cent.

HEAVY WATER

The problem of the association of water is complicated by the heavy and light

hydrogen and oxygen isotopes in the molecule. It is obvious that these two problems can no longer be considered separately. In fact, Bingham and Stevens (1934) find that the extra proton in the nucleus of hydrogen has a profound effect upon the association of water, *heavy water being inert as a result of its low association*. Their calculations indicate that deuterium oxide is very much less associated than is ordinary water, the association factor being 1.34 as compared to 2.50 for ordinary water.

The existence of a heavy hydrogen isotope was suggested by Birge and Menzel (1931) and discovered by Urey, Brickwedde, and Murphy (1932). Washburn and Urey (1932) found that the heavy isotope was concentrated in water which had been subjected to electrolysis as in the manufacture of oxygen. Lewis and later Taylor prepared almost pure heavy water by an electrolytic method (cf. Urey's review, 1933). Kendall (1933) asserts that he obtained unpublished evidence of the electrolytic fractionation of water before Washburn, and Thomson (1934) believes that he observed the heavy isotope of H in 1911.

Several résumés of the recent developments in this important field have appeared (*Nature*, 1933, vol. 132, pp. 536-538; and 1934, vol. 133, pp. 197-198; Aston, 1933; Urey, 1933; and Frerichs, 1934) so we shall refer only to the properties of deuterium oxide likely to be of physiological interest.

The terms deuterium for heavy hydrogen and protium for light hydrogen proposed by Urey, Brickwedde and Murphy (1933) (1934) are probably more suitable than subsequently suggested terms such as diplogen of Rutherford (1933), and barhydrogen of Wood (1933) (cf. also Brogton, 1934; Harkins, 1934; and Ficklen, 1934). Sidgwick (1934) defends the term

diplogen which means "making diploon" the nucleus of the heavy hydrogen. He points out that deuterium means "second substance" but the second particle after the proton should be the neutron. Fortunately the symbol D for H^2 is widely accepted. The nucleus of D was first regarded as an association of two protons and an electron but the discovery of the neutron and the positron (positive electron) has given alternative possibilities for the nucleus (deuteron). According to Sexl (1933) the proton is not a fundamental particle but is a neutron and a positron. Thon (1933) takes the same view and remarks that if the neutron were an aggregate of a proton and an electron

water (cf. Urey, 1933) containing only 0.01 per cent of the normal H the density is 1.1056 at 25° and B. P. 101.42°, freezing point +3.8° and the point of maximum density at about 11.6°. The viscosity is higher and surface tension lower (Table 6). The motility of ions is lower in the pure H^2H^2O (Lewis and Doody, 1933) and the solubility of salts is also lowered (Taylor, Caley and Eyring (1933)), the difference being -7.2 per cent in the case of NaCl. The higher boiling point of the pure heavy water indicates that separation of the isotopic forms can be effected by fractional distillation to a slight extent (Lewis and Cornish, 1933). Uhlmann (1934) reports that old storage batteries contain a slight excess of D.

It is clear that the physical properties of highly concentrated heavy water are of limited biological importance, but the chemical influence of deuterium is extremely significant, especially since an

TABLE 6
Some Properties of Heavy Water (Selwood and Frost, 1933)

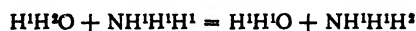
	ORDINARY WATER	HEAVY WATER		
		31%	91%	100% (calc.)
Density, d_{40}^09982	1.03140	1.0970	1.1056
Viscosity.....	10.87	11.4	13.7	14.2
Surface tension.....	72.75	71.5	68.1	67.8 dynes/cm.

Taylor and Selwood (1934) later give the density of 100% D_2O (25°C.) as 1.1079 and the viscosity 12.6.

hydrogen atoms should be converted spontaneously into neutrons and neutrons should be more numerous. From these considerations the deuterium nucleus may consist of two neutrons, conceived as primary uncharged particles of mass 1, and one positron.

The commercial electrolysis of water concentrates the heavier isotope of hydrogen and according to Washburn and Urey (1932) the heavier isotope of oxygen, O^{18} , but the heavy oxygen is not always enriched by further laboratory electrolysis (Selwood and Frost, 1933). The specific gravity of the residual water rises continuously as the electrolysis proceeds, and this is accompanied by a rise in the freezing and boiling points and a decrease in the refractive index. For water of specific gravity 1.0014, the changes are F. P. +0.05°C. and B. P. +0.02° (Washburn, Smith and Frandsen, 1933) and in the concentrated heavy

exchange between the normal H in compounds and the heavy H in isotope water and in deuterium gas may take place. Lewis (1933) describes the interchange of isotopes in an aqueous solution according to the following equation:



in which NH_3 gas is passed into heavy water at 0°C. One mole of water absorbs nearly one mole of NH_3 and since ammonia has 3 H atoms, while water has two, more than half of the H^2 in the system will escape when the ammonia is pumped off. A sample of heavy water having an excess density of 0.000182 was treated in this way and the remaining water had an excess density of 0.000085 or at least 0.000097 of

the original excess density was due to H^2 . Another part was treated with sulphur dioxide which removes the excess of O isotope by a corresponding reaction:



and it appeared that of the original density excess at least 0.000073 was due to O^{18} . Thus heavy water of low concentration from commercial electrolytic cells (which was the first to be tested biologically (T. C. Barnes, 1933a)) contains a relatively large proportion of heavy oxygen which is not enriched by special laboratory concentration of heavy water. This may be important for the interpretation of the favorable biological effect of 0.06 and 0.4 per cent heavy water in contrast to the so-called "lethal" influence of very high concentrations. Webb (1934) states that in heavy water of low concentration used as raw material for concentration processes one half of the excess density is produced by O^{18} . Upon continued electrolysis the oxygen isotope remains constant as shown by the fact that the increased density of discharged water of the apparatus is due to the oxygen isotope only.

Oliphant (1933) reports an exchange between heavy hydrogen gas and normal water over an interval of several weeks and Horiuti and Polanyi (1933) find that the exchange is greatly catalysed by platinum black, possibly due to the ionisation of H corresponding to the electromotive process of the H electrode. They suggest that in the absence of Pt the walls of the vessel may act as a catalyst. It will be of interest to determine what catalytic influences in protoplasm may effect deuterium exchange. Gould and Bleakney (1934) report that the concentration of deuto-hydrogen mixtures in contact with water in a clean glass vessel remains constant. The work of Crist and Dalin

(1933) indicates an exchange between water of 1 per cent deuterium concentration and ordinary hydrogen in a quartz tube at 800°C. Bonhoeffer and Rummel (1934) performed the opposite experiment, i.e., they showed that ordinary hydrogen gains weight when exposed to heavy water (with Pt as catalyst).

The exchange reactions are of great biological interest for they offer the possibility of introducing more deuterium into living organisms exposed to heavy water. Pacsu (1933, 1934) finds an instantaneous replacement of the displaceable H in glucose in heavy water but this does not change the value of the specific rotation for the wave length of Na light. According to Halford and Anderson (1934) deuterium is introduced into acetone dissolved in heavy water containing a small amount of potassium carbonate. The effectiveness of an alkaline catalyst argues for a mechanism involving the enol form, and they doubt that in an organic compound not susceptible to such a reaction any replacement of protium by deuterium can be realized by direct contact with water. Lewis and Schutz (1934) show that in deuto-acetic acid the heavy hydrogen is present in the COOH and not in the methyl group. Bonhoeffer and Klar (1934) consider deuterium exchanges in sucrose and sodium acetate. They regard enolization as favorable to hydrogen exchange. Hall, Bowden and Jones (1934) worked with 2 per cent heavy water (which is near the concentration most suitable for physiological experiments) and found (1) no interchange of hydrogen during brief contact, potassium hypophosphite, potassium acetate, sodium benzoate, hydrogen gas, (2) one third of the hydrogen in ethylene glycol immediately exchanged, (3) extent of exchange increasing with time of contact, potassium acetate, hydrogen gas. They state that

the hydrogens of the acetate group are not wholly inert even when nothing is added to promote enolization. In one run, after sixty-six hours of contact, 34 per cent of the hydrogen in the salt had exchanged. It had been previously shown (T. C. Barnes and Larson (1933)) that an incubation period is necessary for deuterium exchange in the enzymes, amylase and zymase in 0.06 per cent heavy water. It is of interest to note that Cavanagh, Horiuti and Polanyi (1934) find that bacteria (*B. coli*) are able, like Pt black, to catalyse the reaction:



when the partially heavy hydrogen is shaken in a sealed reaction vessel with a de-aerated saline suspension of bacteria.

According to Lewis and Schutz (1934b) the large difference in vapor pressure between hydro- and deuto- forms of such substances as water and NH_3 is almost entirely due to the greater strength of the D bond as compared to the H bond. The same authors (1934c) describe the alteration in the properties of substances having H replaced by D, i.e., the ionization constant of deutoacetic acid is less than one third that of acetic acid in common water. This enormous shift in equilibrium shows how much more tenaciously a deuteron is held by a pair of electrons of another atom than is a proton. The ionization of an organic acid involves the separation of H^+ or D^+ from a pair of electrons of a carboxyl oxygen.

The biological experiments with heavy water are developing so rapidly at the present time that it is impossible to present an adequate summary. Lewis (1933c, 1934) found that tobacco seeds failed to germinate in nearly "pure" H_2O and developed at half the normal rate in 50 per cent H_2O although the seedlings appeared normal after a month's time.

Seeds which had remained three weeks in "pure" H_2O showed some germination when transferred to normal water but the sprouts were thin and soon died. Lewis suggests that when the heavy water first began to permeate the seeds, it was diluted by the "bound" water already in the seeds and produced a medium in which germination could begin but that as soon as the total water within the seed reached a high concentration in heavy hydrogen, the process of germination was stopped. Lewis also reported preliminary experiments indicating that pure heavy water may remain bacteriologically sterile. *Planaria* in 90 per cent H_2O for four hours showed a 50 per cent mortality. A mouse was given 0.66 gr. of D_2O which would be the equivalent of the consumption of 4 to 5 litres of heavy water by a human being. The mouse survived and seemed normal the next day but during the experiment "he showed marked signs of intoxication. While the control mice spent their time eating and sleeping, he did neither, but became very active, running and leaping about. . . . The more he drank of the heavy water, the thirstier he became." Taylor, Swingle, Eyring and Frost (1933a and b) state that 92 per cent heavy water will not support *Rana clamitans* tadpoles, *Lebistes*, *Paramecium* and *Planaria* but they report that 30 per cent concentration has "no effect" over a period of three days. However, they referred to an obvious toxic action rather than the modification of a normal physiological process.

These experiments with highly concentrated deuterium oxide throw little light on the physiological significance of the heavy hydrogen isotope but are valuable contributions to what Just (1930) has aptly termed "the literature of cellular death." Results with heavy water containing a deuterium content slightly above that in ordinary water were secured by

one of us (T. C. Barnes, 1933a) in May, 1933, prior to the work on pure D_2O . These experiments with 0.06 per cent heavy water of density 1.00006 (kindly determined by Dr. E. Ball, 1933) were designed to show the isotope effect under conditions approaching the state of undisturbed living matter in the sense of Crozier. All ordinary water contains a small amount of deuterium, the estimates of the naturally occurring proportion of heavy hydrogen running from 1 part in 4,500 (Birge and Menzel, 1931) to about 1:30,000 (cf. Aston, 1933) but the determinations of Bleakney and Gould (1933) and Lewis and Macdonald (1933), i.e., 1:5,000 and 1:6,500 respectively are perhaps most widely accepted (confirmed by Taylor and Selwood, 1934). The latter results would indicate that the isotope water employed in the *Spirogyra* experiments (cf. T. C. Barnes, 1933a) contained two to three times the deuterium of the controls.

Goldsmith (1934) shows that the disintegration of D in stars leads to an abnormally low D:H ratio in stellar atmospheres, i.e. 1:600,000.

There is evidence of a slight variation in isotopic composition in nature (besides that of the radio active elements). Thus water from the Dead Sea is 2.1 ± 0.5 parts per million heavier than ordinary water, Great Salt Lake water 2.7 ± 0.7 heavier, and water from Rasorite (native borax tetrahydrate) is 6.9 ± 10.3 heavier (cf. U. S. Bureau of Standards, *Technical News Bulletin*, No. 196, p. 81, 1933). Some methods, perhaps of insufficient sensitivity, do not show the greater density of Dead Sea water (cf. Clark and Warren, 1934). Evaporation from brine apparently concentrates deuterium. Tucholski (1934) regards very slow evaporation (mountain caves) as a more efficient concentrating agent (but cf. Hughes Ingold

and Wilson (1934)). Sea water is heavier by two parts per million than fresh water (Gilfillan, 1934). This difference is possibly a result of natural distillation. From the work of Washburn, Smith and Frandsen (1933) Gilfillan calculates that water vapor contains 2.8 per cent less deuterium than liquid water with which it is in equilibrium. Assuming the natural abundance of D to be 1:5000, he calculates that the first distillate from a large amount of water should be lighter by 0.3 ppm. due to differences in D. Using an abundance figure of 1:630 for O^{18} he considers the total concentration effect to be 5 ppm. On the basis of the Boltzmann distribution theorem, it can be shown that, if in the deeper parts of the ocean statistical equilibrium has been reached, pure water from a depth of 4,500 m should be heavier by a maximum of 7 ppm. than water from the surface. This would indicate separation of isotopes by the gravitational field but Gilfillan found the astonishing result that surface sea water has the same density as a sample from a depth of 4,500 m, indicating that the sea has not reached statistical equilibrium (cf. also Ball, 1933). The *polymer* difference would, of course, disappear when the pressures were equalized. There is a slight physiological concentration of deuterium in plants, willow sap containing water with 2.9 parts per million more deuterium than ordinary water (Washburn and Smith, 1934), (Smith, 1934). According to Dole (1934a and b) there is no natural separation of isotopes for the excess density found in organic samples is due to the O^{18} in the O_2 used to burn the compound or to the concentration of D produced by *condensation* of the derived water. Thus careful determinations show that benzene, kerosene and cholesterol from spinal fluid have a normal D content. But Snow and Johnston (1934) believe that the excess

density of natural butane is not entirely due to the O^{18} in the tank oxygen used in the determination. Stewart and Holcomb (1934) find no difference in the density of water distilled from milk and urine of the same cow and tap water but their method may not have been sufficiently delicate.

The first experiments with dilute heavy water (Barnes, 1933a) showed that mass cultures of *Spirogyra* exhibited much less abscission or cell disjunction and greater longevity in 0.06 per cent deuterium water as compared with ordinary water. According to Lloyd (1926) excessive cell disjunction is a reaction to unfavorable conditions. That this low concentration of the isotope may be significant was further demonstrated (T. C. Barnes and Larson, 1933, 1934) in experiments confirming the longevity effect in *Spirogyra* determined by cell counts and demonstrating the decreased activity of amylase and zymin incubated in the heavy water. The abscission effect is seen only in long filaments of *Spirogyra* and not in the short lengths (5 to 50 cells) isolated for quantitative study in small Petri dishes containing 5 cc. of water samples. Of a total of 16 filament sections containing 355 cells in isotope water, the average cell life was 6 days while in ordinary water a total of 15 filaments containing 322 cells showed an average cell life of only 3 days. *Spirogyra* is particularly suitable for water experiments on account of its high water content, photosynthetic activity, dependence on turgor pressure and filamentous form which permits daily measurements of the same cell. With *S. nitida* immediately after division the cell measures about 200μ and divides again after the typical length of about 390μ is attained although cells may elongate to 475μ or more before dividing. It is significant to note (T. C. Barnes and Larson, 1934) that the greater

longevity in isotope water was observed in all cases despite the wide variation in average cell length. Moore's solution in various concentrations was added to the water samples to eliminate a possible salt impurity, and CO_2 and O_2 were bubbled through the water to rule out an effect due to a difference in gas content. The slightly concentrated heavy water appeared to have little or no effect on the rate of cell division or on the rate of elongation of the cells (we avoid the ambiguous and abstract term "growth"), but had a profound influence on the length of life of the cells in the hypotonic solutions employed. More cell division occurred in the heavy water because the filaments lived longer in it. Increased cell division was observed in *Euglena* kept for forty-five days in 0.06 per cent heavy water (T. C. Barnes, 1934a). The initial population at the beginning, 31,750 cells per cc. increased to an average of 51,112 cells in ordinary water and 59,087 cells in the heavy water. There were 1,900 moving forms per cc. in the ordinary water and 4,400 in the "heavier" water (averages). The cells in ordinary water tended to be clumped together in small groups.

The dilute heavy water had a marked effect on enzyme action—the digestion of starch by pancreatic amylase and the fermentation of glucose by zymin. The retardation of the hydrolyses was obtained when the enzymes had been exposed for a time to the isotope water. With this low concentration, however, there is no apparent difference in reaction rate between the enzyme solutions in isotope water and distilled water controls if the enzyme is not incubated nor when the substrate is incubated in place of the enzyme. The total difference in reactivity between the heavy and light water solutions (10–15 per cent more CO_2 production in the latter) (Fig. 4) was nearly the same

when the zymin was treated for 16 hours or 166 hours, indicating a stoichiometric exchange of H. The progress of digestion of starch by pancreatin was followed by removing alternately five drop samples of the solutions to spot plate depressions and adding a drop of dilute iodine. The erythrodextrin stage was reached in 6 minutes in the controls and 8 minutes in the solutions containing amylase which had been incubated in isotope water for 24 hours.

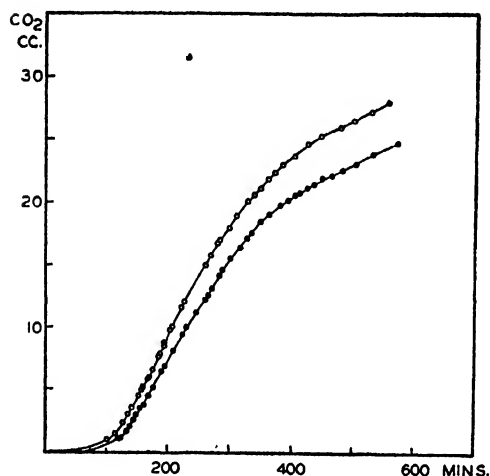


FIG. 4. THE INFLUENCE OF THE HEAVY HYDROGEN ISOTOPE ON ENZYME ACTION (AS DETERMINED BY MR. E. J. LARSON)

The decreased CO₂ production (dark circles) in fermentation by zymin which has been incubated in heavy water of .06 per cent deuterium is compared with the CO₂ production by zymin which has been exposed to ordinary water (open circles) (cf. T. C. Barnes and Larson, 1933). Since the incubation of the substrate (glucose) in heavy water does not produce the reduced activity, Larson's theory postulates the introduction of deuterium in a key position in the enzyme.

After the effect on *Spirogyra* was obtained, our colleague Dr. Oscar Richards kindly consented to repeat the tests with yeast (cf. Richards, 1933) and confirmed our discovery that a slight excess of deuterium in water may be biologically significant. He observed a 26 per cent increase in dry weight of yeast grown in our isotope water, and Meyer (1934) found

the same effect in *Aspergillus*. Taylor and Harvey (1934) later measured the O₂ consumption of yeast in heavy water but were unable to interpret their results (cf. below).

The regeneration of the flatworm *Phagocata gracilis* was tested in the 0.06 per cent isotope water but no macroscopical difference was observed (T. C. Barnes and Larson, 1934). However, the animals were left in the water and after a few months time a striking difference was observed which became slowly more evident—the worms in the light water gradually shrank to one-fifth or less of their original body size while in the isotope water only a slight diminution was seen. A large excess of water was present (50 cc.) containing one drop of Ringer per 10 cc. It is possible that the longevity of *Spirogyra* and the inhibition of shrinkage in the starving planarians are due to retarded enzyme hydrolysis as the amylase experiments suggest.

The body size experiments on *Planaria* were repeated in slightly more concentrated heavy water (0.47 per cent or 1 part deuterium to 213 parts protium) and a new effect appeared (Larson and T. C. Barnes, 1934). The animals in heavy water of this concentration were parasitised by moulds and succumbed within three weeks. In some cases the living animal becomes invested with slime mould and in others is covered with tufts of mycelium. It would appear from the work of Meyer on *Aspergillus* and our *Planaria* experiments that heavy water having a 1:200 deuterium ratio may have a specific effect in stimulating the growth of moulds and possibly bacteria. This property should afford many interesting problems in parasitology and might be of considerable importance in the possible therapeutic use of heavy water of low concentration. Klar (1934) objects that

moulds in our experiments were stimulated by paraffin impurities but he is not clear in explaining how a trace of organic matter could influence moulds grown with added nutrients (cf. Meyer 1934; Richards 1933).

Von Hevesy and Hofer (1934) used heavy water of about this composition, 0.5 per cent in their work with goldfish. They found that the rate of exchange of heavy water of this strength was the same as that of normal water but the experiments lasted only a few hours and no quantitative studies of metabolism etc. were made.

Our zymine effect explains the subsequent work of Pacsu (1934) who observed that fermentation by yeast cells in nearly pure H_2O was nine times slower than in ordinary water, but he did not attempt to limit the effect to the enzyme. The results are in harmony with the increased dry weight found in yeast grown in isotope water by Richards (1933). On the other hand Macht and Davis (1934) report that fermentation experiments with yeast and 4 per cent cane sugar in ordinary and 0.06 per cent deuterium water showed no difference. This we think was due to the fact that the zymase was not incubated in the heavy water prior to the test which we showed to be necessary with very low concentrations of heavy hydrogen. These authors found a slight inhibitory effect on germination of *Lupinus* seedlings but no apparent results with mammalian tissues (contraction of intestinal loops, etc.).

However, Meyer (1934) working with dilute isotope water (1 part in 213) confirmed our original view that a slight excess of deuterium may be biologically significant. He found that the dry weight of *Aspergillus* mats in the heavy water was 16 times that of the felts grown in ordinary distilled water (plus nutrients in each case) and that the fruiting was "greatly diminished." These results resemble our

previous experiments (Barnes and Larson, 1934) showing a greater spreading of *Oscillatoria* in unbuffered isotope water of 0.06 per cent concentration.

Brief mention must also be made of recent sporadic tests of heavy water which require re-interpretation. Sugiura and Chesley (1934) announce that the proliferating capacity of the mouse sarcoma 180 and mouse melanoma is unaffected by 14.8 per cent and 40 per cent heavy water when isotonic. They place the tissue in heavy water for 12-24 hours at 4-5°C. at which temperature the chemical reactions of growth favorable for exchange of isotopes are inhibited. The tissue is then removed from heavy water and transplanted into a normal animal where of course it grows at the higher temperature. No quantitative data are given relative to the growth rate which, moreover, is not measured in an environment rich in D. There is no previous evidence for a "lethal" action of heavy water of the concentrations used by these authors who overlook the time factor necessary for the slow influence of deuterium. They find a 156 per cent increase in weight in tumor tissue swelling in 14.8 per cent heavy water as compared to 130 per cent in ordinary water which they do not regard as a deuterium effect but one depending on a difference in pH of the isotope water, being apparently unaware that it had been shown previously (T. C. Barnes and Larson, 1933) that isotope water has a higher pH which may depend on the deuterium content (lower mobility of D or change in dissociation constant of dissolved substances). Harvey and Taylor (1934a) set out to find the cause of the "deleterious effect of heavy water for living things" following Lewis in the use of high concentrations of deuterium. They fail to realize that 100 per cent heavy water represents a five thousand fold increase in a normal constituent of protoplasm. This

old fashioned physiology of subjecting organisms to the most extreme conditions possible is fortunately yielding place to a more careful study of the organism as undisturbed living matter in which slight increases in constituents may reveal their rôle in the normal animal. Taylor and Harvey find as Lewis did that 86 per cent heavy water has a depressing action, in this case on the oxygen consumption of bacteria. It is obvious, however, from their Fig. 1 representing the O_2 consumption of marine bacteria that their "control" of 0.18 per cent D_2O has a higher rate than the ordinary water experiment, confirming our results that dilute heavy water may have a stimulating action. These authors, however, ignore previous work and do not realize the significance of the slight increase in O_2 consumption in 0.18 per cent D_2O (which probably would have been more significant if a longer time interval had been used and the number of bacteria counted). In their study of the O_2 consumption of yeast (Taylor and Harvey, 1934b) these workers again find that there is more O_2 consumed in 0.18 per cent D_2O than in ordinary water but fail to realize the significance of this result (seen clearly in their Fig. 1). It would be interesting to compare their results with the slightly reduced activity of zymon (Barnes and Larson, 1933) and the increased dry weight of yeast (Richards, 1933) in dilute heavy water but they do not have any measurement of the quantity of yeast at the end of the experiment.

Hackh and Westling (1934) suggest that accumulation of heavy water by evaporation in the human body may cause senility, being apparently unaware that the first biological experiments showed that a low concentration of D_2O increases longevity of cells.

Although the nature of the action of the heavy isotope on protoplasmic activities

must remain conjectural until more work is completed, it is evident that a number of possibilities may be considered. (1) Lewis (1933c) suggests that the "selective power of living organisms may segregate the isotopes in some of the substances necessary to growth." He originally considered heavy water as "lethal" to living organisms, but later (1934) he writes "heavy water is never toxic to any high degree and it is tolerated in high concentrations by lower organisms." He suggests that the rate of vital processes seems to be roughly proportional to the fraction of total hydrogen which is H^1 . However, in this connection it should be remembered that a very slight concentration of isotope may have a relatively enormous effect, probably due to its influence on a key reaction. (2) It is also possible (T. C. Barnes, 1933) that an explanation may involve bound water in colloids which is known to be of greater density than "free" water. This might exert a stabilizing effect. Moreover, Washburn and Smith (1933) have shown that heavy water molecules are preferentially adsorbed on charcoal from deuterium water of approximately the same concentration as used in the *Spirogyra* and enzyme experiments. Woodward and Chesley (1934) report that gelatin absorbs 20 per cent less of 90 per cent heavy water in a given time than it does ordinary water. (3) The heavy water effects may be conditioned by a pH difference (T. C. Barnes, 1933) especially since Bernal and Fowler (1933) have calculated that the heavy isotope has only one-fifth the mobility of the light (cf. also Lewis and Doody, 1933). A slightly higher pH in heavy water of 0.06 per cent and 0.5 per cent concentration was found (Barnes, 1933) which may be a direct result of the lower H activity or its influence on the dissociation of dissolved substances. The

inhibition of abscission in *Spirogyra* is seen in buffered heavy water but not the increased spreading of *Oscillatoria*. However, the digestion of starch proceeds more slowly in heavy water in spite of the fact that the latter is nearer the optimum pH (T. C. Barnes and Larson, 1933). (4) The biological results may be entirely traced to the influence of deuterium on enzyme action (T. C. Barnes and Larson, 1933, 1934). The work with amylase and zymine suggests an exchange between the excess deuterium in some key position of the enzyme molecule which was first proposed by our colleague Mr. E. J. Larson. Perhaps there is an exchange of the amino group or peptide binding in the enzyme. Eyring and Sherman (1933) reporting the general chemical activity of the heavy isotope, apart from enzymes, states, "All chemical reactions having a positive temperature coefficient go about half as fast or less at ordinary temperatures with the heavy as with the light H. It will be possible to single out such reactions in biological processes." (5) Bio-electrical potentials may be changed by a suppression of ionization brought about by the presence of the heavy isotope. (6) Bingham and Stevens (1934) state that heavy water is inert due to low association (reduced trihydrol content), which would apply principally to the concentrated deuterium oxide which has a low association factor. This may prove to be a line of contact between the ice water and heavy water experiments. Cabrera and Fahlenbrach (1934) are probably mistaken in their suggestion that concentrated heavy water is more strongly polymerized than H_2O . They did not determine the association factor but found that the difference in the diamagnetic susceptibility of D_2O is less than that of H_2O at the melting point. Another possible connection may be through the work of Uhlmann (1934) who

is investigating a possible concentration of H^2 during sublimation (evaporation) of ice and snow. This might help to explain the activity of organisms in melted ice water in the spring. (7) A small concentration of deuterium oxide may be an essential constituent of protoplasm. For example, Ca may be quite essential in small amounts quite apart from its action on a living organism in a saturated solution.

Whatever the explanation of the biological effect of heavy water may be, it is clear that physiology is greatly indebted to Washburn and Urey for their discovery of D_2O .

A third isotope of H of mass three, tritium (T), was announced by Latimer and Young in 1933 (*Phys. Rev.*, 44: 690) and was found to result from the collisions between deuterons of high energy by Oliphant, Harteck and Rutherford (1934). Tuve, Hafstad and Dahl (1934) find H^3 (T) in concentrated deuterium samples and Lozier, Smith and Bleakney (1934) report an abundance ratio $T:D = 5:10^6$ in pure heavy hydrogen. This means that the ratio $T:H$ in natural hydrogen is probably of the order $1:10^9$ and has not yet become physiologically significant. However, Hornwell, Smyth and Van Voorhis (1934) have concentrated the third hydrogen from the natural 1 part in 200,000 in pure deuterium to 1 part in 5,000 D which suggests that tritium may ultimately be obtained in biologically significant concentrations.

BOUND WATER

We do not propose to review the problem of "bound" water in colloids and living tissues for nothing is known about the possible effect of polymerization on the degree of bound water. Gortner (1930) believes that an appreciable fraction of water in organisms is not "free," as

judged by the fact that only part of it freezes even at very low temperatures; but Hill (1931) finds little evidence for bound water as measured by vapor tension which, however, is not always a direct indicator of the state of water (for example, ice evaporates as a polymeric vapor). Greenberg and Greenberg (1933) also conclude that practically all the water in colloidal solutions is free as judged by its ability to dissolve urea and glucose. Since bound water is more dense (cf. Barron, 1931) than free water, it is not composed of the bulky "trihydrol" aggregates, but it is interesting to note that according to Marinesco (1930) the dielectric constant of "bound" water in tissues appears to be the same as that of Ice No. VI, which is known to exist only under enormous pressures. It would appear that although some bound water is present in the living cell, there is enough free water to permit the existence of trihydrol molecules. The rapid spreading of feathery ice crystals in *Amoeba* protoplasm at -0.8°C . (Chambers and Hale, 1932) supports the view that there is a large proportion of "free" water. Kedrowsky (1931) regards the free water as that which is available for chemical transformations without changing the plasma colloid structure. It must be remembered that the free-bound water equilibrium is not a static one (Spek, 1928). Gortner and Gortner (1934) have recently defended the bound water concept and they conclude that the bound water values as determined by the cryoscopic method parallel the physiological responses of plants to environmental conditions. Bull (1934) successfully meets the criticisms of Grollman (1931), for the negative amounts of bound water found by the latter are due to the fact that the KCl used in Grollman's method is adsorbed by the colloids along with the water. A direct line of contact between the bound water problem and the

structure of water discussed in this review is afforded by the results of Kolkmeijer and Favejee (1933), showing that many of the x-ray lines from emulsoid sols at ordinary temperatures correspond to ice lines. Of 21 lines on a starch picture, 15 correspond to the first 15 of a possible total of 18 ice lines. The inference is that the bound water is oriented on the surface of the particles in the ice lattice. It is probable, however, that the water molecules in the bound state are not the same as the trihydrol aggregates, because the latter have a lowered density. The hypothesis may be considered that the bound water is composed of trihydrol molecules whose density has been increased by pressure, and this is in agreement with the findings of Marinesco (1930).

VAPOR PRESSURE

It is obvious from the above historical survey of the polymerization of water that further investigation is needed in this important field. It is hoped that our work on the biological effect of "ice-" and "steam water" will stimulate more extensive research on the properties of water, even if this proves fatal to our present working hypothesis that trihydrol aggregates play an essential rôle in certain types of living cells. In this connection one may mention the recent experiments of Menzies (1932), who compared the vapor pressure of 10 cc. samples of recently boiled and frozen distilled water at the same temperature. The apparatus consisted of two 25 cc. Pyrex bulbs connected by a water manometer. Under these conditions Menzies found no appreciable difference in vapor pressure. It is doubtful, however, if vapor pressure is a direct indicator of the concentration of water polymers. In fact, it is the only important property of water which previous investigators have not studied in relation

to association. The vapor tension of ice and of water is treated in *Ice Engineering* by H. T. Barnes (1928, pp. 31-33, 56-67). Barnes and Vipond in 1909 found the surprising result that the heat of vaporization of ice at 0°C. is almost identical with that of water at 0°C., which indicates that ice evaporates as a polymeric vapor. In ordinary evaporation of ice the change of the solid vapor to ordinary vapor takes place just outside the surface and would escape detection in the usual vapor pressure measurements.

As was mentioned above, Baker (1927) used vapor pressure as a criterion for association changes but his work was criticized by West and Menzies (1929) and Wright and Menzies (1930).

Little is known concerning trihydrol in the air but it acts as nuclei for the formation of rain drops, fog and hoar frost and the presence of ice particles in the upper atmosphere is shown in the phenomenon of sun dogs and moon dogs (H. T. Barnes, 1928, p. 10).

RATE OF FREEZING

Inasmuch as ice exhibits anomalies in its mode of evaporation it is suggested that other methods than those involving vapor tension might yield more direct indication of the concentration of liquid ice in water. Judging from the discrepancies in the papers reviewed above it appears that we have at present no means of determining the precise degree of association and concentration of water polymers, but it seems reasonable to infer that "ice water" will contain more trihydrol for a limited time at least than "steam water" immediately on condensation. On the colloidal theory of water, ice forms when the trihydrol concentration reaches the saturation point, so it occurred to one of us (T. C. B.) that it would be of interest to determine the *time*

required for equal samples of "steam-" and "ice water" to freeze at the same temperature. It was found that to cc. of fresh ice water, warmed rapidly to 10°, would freeze three times as rapidly as condensed steam water cooled rapidly to 10°; both samples, of course, being subjected to the same freezing temperature. On the basis of the colloidal theory these results might be interpreted on the grounds that, since ice forms when the dihydrol is saturated with trihydrol, water containing more liquid ice aggregates would take a shorter time to freeze than condensed steam water containing less trihydrol. However, *great caution* must be exercised in interpreting new experiments of this nature, but they seem to give tentative support to our hypothesis. The ice was obtained from absolutely clear portions of large blocks of commercial ice. This ice when perfectly clear yields water of great purity. H. T. Barnes (1928, p. 59) states "my own tests on water from melted ice show it to be so closely allied to the purest distilled water that it is indistinguishable by a chemical examination. Provided ice is clear from air pockets it may be safely used, even when frozen from a polluted source." In the manufacture of artificial ice there is an opaque core into which all the foreign matter from the water has been thrust. An ice crystal cannot form unless it is absolutely devoid of foreign material. In a recent study of the crystal structure of ice W. H. Barnes (1929, p. 676, see also fig. 3) states "all attempts to grow single crystals of ice with well developed faces failed. Only needles could be obtained. The crystals finally employed . . . were found in commercial, artificially frozen ice. . . ." Indeed, Zsigmondy (1920) recommends melted ice water as the purest water obtainable for ultra-microscopical work. Frozen steam water was used in some of

the *Spirogyra* experiments, but as Plyler (1924) states, it is difficult to freeze small quantities of distilled water to obtain ice with large crystals and free from bubbles. The crystals grow slowly with aging, as indicated by Plyler's photograph of commercial ice kept for several months. The lines of separation between the large crystals stand out on melting, a fact which

steam water cooled rapidly to the same temperature, but we have not yet prepared freezing time curves for this type of ice water.

The original freezing time curve was obtained by placing samples of water from "large crystal" clear commercial ice and condensed steam water in test tubes in a wooden rack outside in December, 1932.

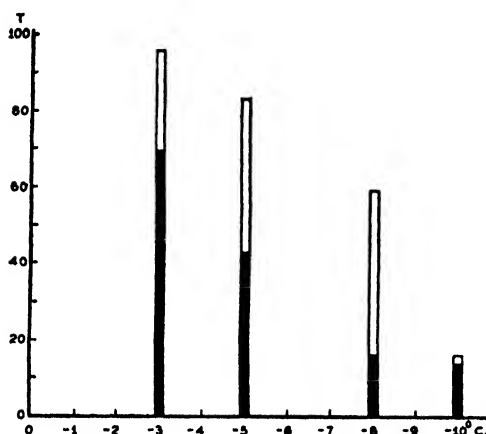


FIG. 5

FIG. 5. FREEZING TIME CURVE FOR 10 CC. SAMPLES OF ICE WATER AND STEAM WATER BOTH BROUGHT RAPIDLY TO 10°C.

Abscissae: temperature of air in degrees below zero C. Ordinates: time in minutes required for freezing. Black columns: ice water. Unshaded columns: steam water. The test tubes were placed outside in a test tube rack during cold weather in December, 1932. Under these conditions the water freezes more slowly and the end point (sudden appearance of feathery crystals throughout the sample) was more readily seen than when the tubes are immersed in a brine freezing mixture.

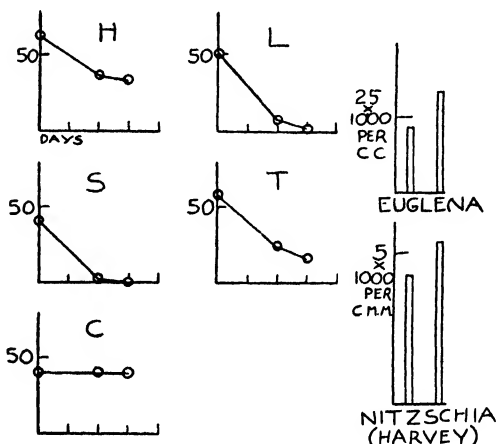


FIG. 6

FIG. 6. THE EFFECTS OF VARIOUS KINDS OF WATER ON SPIROGYRA, EUGLENA AND NITZSCHIA

The *Spirogyra* graphs (H, L, S, T, C) represent the number of living cells in short sections (50 cells) of the same filament in heavy water, H, of low concentration (.06 per cent deuterium); in ordinary light water, L; in steam water renewed twice daily, S; in ice water, which on our theory contains more trihydrol, T; and in the control, C, in pond water (cf. T. C. Barnes and Larson, 1933). Abscissae: time in days; ordinates: number of living cells. The *Euglena* chart shows the relative population in condensed steam water (left) and ice water (right) after two weeks (T. C. Barnes and Jahn, 1933). The *Nitzschia* chart shows the increased population (right) in sea water to which ice water has been added (Harvey, 1933.) (See text.)

we have also observed in our own samples. This hard, clear "large crystal" ice seems to yield water of greater sustaining action for *Spirogyra* than that from bubbly fine crystallized ice obtained by the rapid freezing of small quantities of steam water. It is suggested that this latter type of ice does not yield as rich a solution of trihydrol. However, ice water from frozen steam water freezes more rapidly than

(fig. 5). This simulated natural conditions and also afforded greater visibility than is possible when the tubes are surrounded by brine mixture in a pail or in Dewar flasks.

In collaboration with Professor F. E. Lloyd, freezing experiments were carried out at McGill University in December, 1932, to test water prepared under the same conditions as those obtaining in the *Spiro-*

gyra experiments of 1931 (Lloyd and Barnes, 1932). It was found that the water from the same quartz still did not freeze as rapidly as water from clear river ice, thus supporting the New Haven freezing experiments.

PHYSIOLOGICAL EFFECTS OF ICE WATER

Experiments concerning the effect of ice and steam water on *Euglena* have been described briefly (Barnes and Jahn, 1933) and the present paper presents a more detailed description of these experiments. The stock cultures of *Euglena gracilis* were grown under bacteriologically sterile conditions in a medium of inorganic salts and hydrolyzed casein (Jahn, 1931), and also in the same salt solution under non-sterile conditions. In each experiment a large number of *Euglena* was taken from one type of culture and washed several times by centrifuging with water which had been distilled several weeks previously. The washed cells were then divided equally into two containers and fresh ice water was added to one-half while the same amount of fresh steam water was added to the other half. The steam water was prepared from a Pyrex still and the ice water was obtained from commercial block ice, the purity of which has been discussed previously (Lloyd and Barnes, 1932, and elsewhere in the present paper). Both kinds of water were at approximately the same temperature (10° – 15°) when poured on the organisms. Since *Euglena gracilis* grows well at a temperature as high as 30°C . and the narrowest recorded range of non-lethal temperatures for the species is 0 – 37.5° (Jahn, 1933), any lethal effect could not be ascribed to these temperature differences. The initial concentration of organisms (in thousands per cc.) was determined (method described by Jahn, 1929), and the organisms were placed in centrifuge tubes and kept at

approximately 10°C . Under these conditions any slight difference in temperature between the types of water would rapidly disappear. Three tubes of organisms in each kind of water were used for each experiment; therefore, each experiment was in triplicate.

In seven of the eight experiments the water was changed daily by centrifuging; in the eighth it was changed twice a day, and in this last experiment samples of the water used were subjected to the freezing tests described below. The tubes were well shaken to redistribute the organisms throughout the tube after centrifuging, and this shaking also tended to equalize the gas tensions of the water. The tubes of experiments IV and VI were placed in an ice chest containing a 25-watt light globe, 15 inches from the cultures. The temperature of these cultures was approximately 10° . The tubes of the other experiments were placed near a closed north window, and the temperature of these cultures was 10 – 15°C . The results of the eight experiments are shown in Table 7. Each concentration given is the average of the count taken on two samples from each of the triplicate tubes. No one count differed by more than 15 per cent from the mean of the six counts.

The data show that in seven of the eight experiments a relatively larger amount of growth occurred in the ice water. The average increase in concentration of organisms in the steam water was 32 per cent (16.4 compared to 21.7 thousand per cc.), whereas the increase in the ice water was 105 per cent (16.4 to 33.6 thousand per cc.). Cells in the ice water of all experiments except experiment VII were, on the whole, much more motile than those in the steam water, and after the first few days there was an increasing tendency of the organisms in the steam water cultures to remain in the bottom of the tube. The

ice water cultures also showed this tendency to a certain extent, but it always occurred first and was more pronounced in the steam water. Also, in the steam water there was apparently a much larger percentage of dead cells at the end of the experiment. Dead cells do not disintegrate immediately under the conditions of the experiment but remain in the water for at least two weeks, during which time they slowly become decolorized. Since it is quite impossible to tell by observation the percentage of green euglenas

contradictory results obtained on the effect of various substances on *Euglena gracilis* (Zumstein, 1900; Ternetz, 1912; Pringsheim, 1912; Mainx, 1928; Jahn, unpublished observations). Certain sugars sometimes produce a large acceleration of growth, while at other times these same sugars produce a deceleration and encystment. Jahn (in a forthcoming publication) has obtained both types of results under the same conditions of light and temperature and by using media tubed from the same solutions at the same time.

TABLE 7

The Effect of Pure Ice Water and Pure Steam Water upon the Growth of Euglena gracilis. The Water was Changed Daily in all Cases Except in Experiment VIII in Which it Was Changed Twice Daily. For Further Explanation See Text

EXP.	PREVIOUS MEDIUM	INITIAL CONC.	DURATION OF EXP.	FINAL CONC.		RATIO OF FINAL CONC'S. (ICE WATER) (STEAM WATER)
				Steam water	Ice water	
I	Peptone	15	15	18	40	2.2
II	Peptone	16	10	22	36	1.6
III	Peptone	18	14	21	36	1.7
IV	Peptone	15	14	20	35	1.7
V	Salts	17	13	20	30	1.5
VI	Salts	15	14	20	26	1.3
VII	Peptone	10	10	20	13	.6
VIII	Peptone	25	16	33	52	1.6
Total.....		131		174	268	1.54
Average		16.4		21.7	33.4	1.54

which are dead, figures for these percentages are not available. The motility effect was reversed in experiment VII, the steam water cultures showing a greater motility as well as a greater increase in number. In this experiment the results are directly contradictory to those of the other seven experiments, and as yet we have no proven explanation for the results. It does not seem to have been caused by an experimental error, and an explanation of this contradiction might involve factors which would also account for previous

These contradictions are believed to be caused by the metabolic condition of the cell at the time the experiment is started, and there is considerable cytological evidence concerning reserve materials which would make this theory seem plausible, but as yet it has not been proven.

The effect of low concentrations of salts in the ice water and steam water was investigated in unpublished experiments by T. C. Barnes and M. Glass on *Spirogyra nitida*. To the water prepared as above was added 2 per cent concentrated Moore's

solution, an amount which should suppress any difference in the traces of ordinary salts in the two types of water. Large, healthy filaments of *S. nitida* were placed singly in the two solutions. These solutions were renewed daily, and at the end of four days the number of colorless and shrunken and the number of normal cells were counted. In a typical filament, out of 112 cells in the steam water, only

physiological effects on these organisms. The curves of Wills and Boeker (1932) show a very striking hysteresis effect in the same temperature range as used in these experiments, and, according to their data, at least five hours is required for adjustment of polymer equilibrium; therefore, one is led to believe that the present effect may be due to the ratio of the water polymers. Since our two types of water

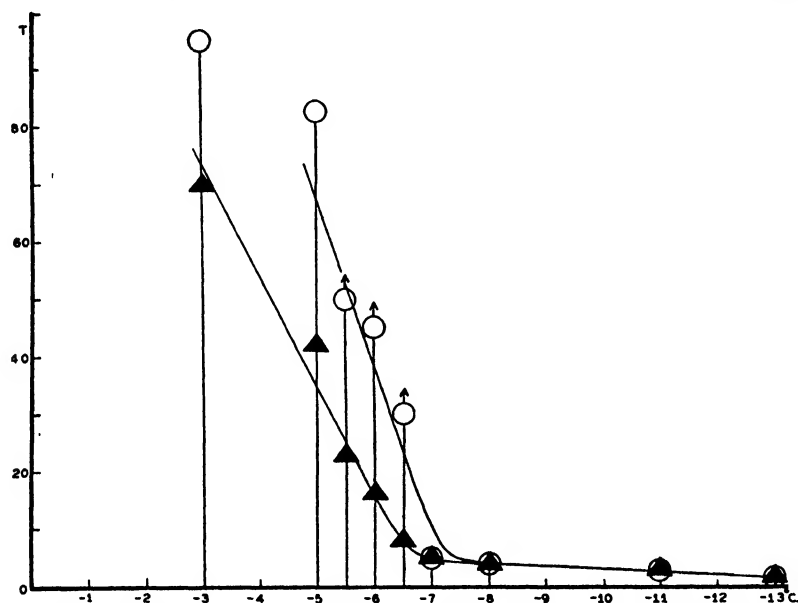


FIG. 7. FREEZING TIME CURVE FOR 10 CC. SAMPLES OF ICE WATER AND STEAM WATER BOTH BROUGHT RAPIDLY TO 10°C. IN TEST TUBES IN ICE-BRINE MIXTURE

Abscissae and Ordinates as in Fig. 5. Triangles, ice water samples; circles, steam water samples. In the latter case the samples freeze so slowly that the times given in three cases (circles with arrows) are those elapsing until the temperature of the brine mixture rose above the constant temperature. The reading at -3 is taken from Fig. 5 for it is difficult to maintain the brine for such long periods at a relatively constant temperature. In general, the freezing times in brine are faster than those in air.

25 (22.3 per cent) were normal; out of 65 cells in the ice water, 54 (80.6 per cent) were normal. It is concluded that any effect due to traces of common salts (present in Moore's solution) coming from the ice would be ruled out.

The present experiments on *Euglena*, as well as the earlier work on *Spirogyra* (T. C. Barnes, 1932; Lloyd and T. C. Barnes, 1932) show that ice water and steam water appear to have decidedly different

had recently undergone a change of state one might expect that the time for readjustment of the polymer ratio should be longer than five hours. How the observed physiological effect is brought about is not known, but the results obtained so far are not incompatible with the original working hypothesis that trihydrol particles influence certain types of cells.

In connection with the *Euglena* work, freezing time experiments were also made

by placing ice water and steam water, both at 10° as above, in a brine mixture at temperatures ranging from -2 to -15°C . Surrounded by the ice-brine mixture the water in the test tubes froze more rapidly than in the preliminary experiments in air, and the water which had been ice immediately before the test froze much faster than the steam water provided the temperature was not below -6°C . (Fig. 7). Finally, Dewar flasks (internal diameter 4.5 cm.) containing brine mixture were employed and samples of the water used in the *Euglena* and later *Spirogyra* experiments were tested at -5°C . at the time of renewal. To eliminate the possible influence of the internal surface of the test tube on the speed of freezing, many tubes were used and reversed in separate tests, i.e., the tube in which ice water had frozen rapidly in one test was used for the slow freezing of steam water in another test. In the Dewar flasks a typical 10 cc. sample of ice water would freeze in 10 to 15 minutes at -6°C ., while steam water would remain unfrozen under the same conditions for as long as 45 minutes. All samples were tested immediately after preparation. Preliminary experiments dealing with samples a day old indicate that some of the difference persists for a considerable time, but further work is necessary before a definite time limit can be placed upon the hysteresis effect. Therefore, in experiments planned to test the effect of water polymers, it is essential that freshly prepared water be used, that this water should be renewed as frequently as practicable under the experimental conditions, and that, if possible, destruction of trihydrol by the addition of solutes should be obviated.

The recent work of Weiss and Nord (1933) indicates that enzyme solutions are more active after freezing which may help to explain some of the biological results.

According to Larson's theory peroxide may be formed when trihydrol breaks down as shown by the guaiacum test (Barnes and Larson, 1933).

Harvey (1933) in a recent comprehensive paper on the rate of diatom growth has considered the suggestion of one of us (T. C. B.) that the production of diatoms may be influenced by trihydrone molecules in the water from recently melted ice. Using *Nitzschia closterium*, he tested the possibility of different water molecules in the following way. Filtered sea water was enriched with phosphate, nitrate, iron citrate and sodium silicate and inseminated with the diatom. Fifty cc. portions were placed in small flasks to half of which were added 10 cc. of recently distilled water and to the other half 10 cc. of the same water which had been frozen and allowed to melt. Harvey states "The experiment was repeated several times and except in the case of one pair of flasks, a greater growth could be distinguished after several days where the ice water had been added." Counts in a representative pair of flasks showed 4,310 cells per cubic mm. with recently distilled water and 5,430 cells per cubic mm. with ice water. In another series, the sea water was partially frozen and allowed to melt, and "in each of the experiments the growth was perceptibly greater in the water which had been partially frozen." Another series of experiments made in November with less illumination did not show the difference. In the *Euglena* and *Spirogyra* experiments we also find that occasionally the effect does not appear, a fact which has not yet been explained. It is interesting that Harvey obtained an ice water effect in spite of the high salt content of his water samples.

Offant (1934) has described what we interpret to be an effect of water polymers on the heart rhythm. If K-poor

Ringer is treated with ultra-violet light it alters the heart rhythm but Offant finds, by irradiating water and salts separately that the effect is on the water molecules. Probably some change is produced in the higher polymer since radiation of heated water (simpler structure) has no effect. Radiation is a powerful agent in the destruction of trihydrol (cf. H. T. Barnes, 1929, p. 296).

Hegarty and Rahn (1934) have recently tested our water theories with *B. coli* cultures. They used ice water from sterile water blanks kept frozen for at least a day and steam water from a sterile Pyrex condenser. The waters were at once brought to 30° and peptone and beef extract added. In a typical run the population increased from 88,500 per cc. to 1,420,000 per cc. in ice water and from 103,500 to 700,000 in steam water. They write "dihydrol is changed strikingly only by vaporization which is also the sole process influencing the growth rate of *Bacterium coli*." Further details may be obtained from the original paper but it is interesting to note that their work indicates a lag in the polymer equilibrium of 4-12 hours.

It was formerly suggested (Barnes, 1932) that the colloidal water particles might render the water more active in a manner analogous to catalysis, but at the present time it does not seem prudent to go beyond the empirical finding that ice water will sustain *Spirogyra* and *Euglena* for a longer time than fresh steam water. The positive results with these holophytic cells also invite the consideration that polymerized water is involved in photosynthesis. The trihydrol or hexahydrol may be built up into a sugar molecule. If melted ice water were stimulating to plants only, it would still be a factor in the increase in the spring plankton as originally suggested (Barnes, 1932) and might

help to explain the richness of plant forms in arctic waters. Hart (1934) regards this suggestion as "rather naïve" in view of the many factors involved (cf. Gran (1929), Braarud and Klem (1931)) but he considers the trihydrol hypothesis as an explanation of the abundance of plankton in cold water. Correspondents have mentioned that some algae do not show the same differences in ice water, and it may well be that various forms have an optimum trihydrol condition, depending on the species. Nor is it impossible that the water polymers have an *indirect effect*, as would occur if they influenced the concentration of catalytically active "unhydrated H ions" in stoichiometrically similar water samples. We have found no consistent pH difference, and both the biological effect and the freezing time phenomenon are evident when the pH is the same (5.9, 6.0, 6.2). This makes it improbable that the CO₂ content of the ice water is the chief factor, but Sutherland (1900) has pointed out that the solubility of substances in trihydrol may be quite different from that in the other water species. Hegarty and Rahn (1934) bubbled their water samples with air to prevent an O₂ deficiency effect.

We must also consider the possibility that the freezing time effect and even the biological results are influenced by the presence of dust particles in the water. Rice (1926) points out that distilled water contains about 25,000 suspended dust particles per cc. and these may be active catalytically, i.e., the oxidation of sodium sulphide is almost entirely a dust reaction and the photochemical decomposition of hydrogen peroxide more closely obeys Einstein's law of photochemical equivalence when dust is removed from the system. Also Pennycuik (1928, p. 1685) writes: "When a gaseous H—O—H molecule is captured through its auxiliary

field by some foreign substance, its exposed field is now more active than the normal, and further as it has surrendered some of its kinetic energy, it now acts as an efficient condensing agent towards other water molecules." However, we do not regard the dust nuclei as the most important factor for two reasons. (1) Burk (1928, p. 1632) doubts the generality of Rice's view and does not consider dust particles as a "great menace to sound investigation." He points out that the effectiveness of dust particles does not compare in magnitude with that of the walls of the vessel. In both the *Spirogyra* and freezing time experiments, the vessels were exchanged repeatedly in the tests, which would rule out any difference in the catalytic effect of the walls. (2) It does not seem probable that the ice water contained more dust particles than the recently condensed water for as Friend (1933, p. 301) states "Tyndall obtained optically pure water by melting clear block ice in a vacuum."

Most critics maintain that the polymerization equilibrium is established instantly. For example, La Mer and Miller (1933), although admitting that negative evidence such as the vapor pressure measurements of Menzies (1932) may be ascribed to insufficient sensitivity of the method, report no difference in the refractive index of water recently distilled as compared with water standing for several days. But La Mer and Miller fail to consider Sutherland's (1900, see p. 466) discussion of the Lorenz-Lorentz formula which suggests that the refractive index and the trihydrol concentration do not tend to diminish toward 0° at the same rate. As was mentioned above, our claims apply especially to water from clear ice consisting of large crystals compared to condensed steam water. We admit that it is theoretically possible that

the equilibrium is rapid; but if this is true, it would leave no explanation for the biological difference in water depending on its previous change of state, the striking difference in freezing times of ice and steam water, the differences in diamagnetism depending on thermal history (Wills and Boeker, 1932), and the exhaustion of the ice-forming power of water at low temperature by the removal of ice (H. T. Barnes, 1929 and Fig. 1 of this review).

CONCLUSIONS

In conclusion we wish to emphasize the importance of water as a neglected component in chemical and biological systems. It is recognized (cf. Heilbrunn, 1928; Adolph, 1930; Gortner, 1930; Kiesel, 1930) that water is the most important component of living matter but it is evident from the foregoing review that a great deal more information is needed on the physical side before we will be in a position to assign specific rôles to water in its various modifications in the living cell. The problem of "water metabolism" has received considerable attention (cf. Buchanan (1930), Adolph (1933), Barbour and Gilman (1934)). Duryee (1933) has supported the important theory that oxidation is inversely proportional to water content; but on the other hand Schieper (1929) holds that the addition of water to the body fluids of certain animals increases the respiratory rate, due on his theory to the osmotic work performed in resisting the disturbance of the salt equilibrium (for example, the gill movement frequency of *Ligia* increases in dilute sea water (Barnes, 1932a)).

Quite apart from the hypothesis that water polymers have specific effects on living matter and that the association equilibrium requires time, it is obvious that the variation of the ratio of water polymers as controlled by temperature,

which is firmly established by the numerous investigations reviewed above, will have to be considered when estimations are made of the physical state of natural waters (e.g., great depths of the oceans, mountain lakes, saline lakes, hot springs, etc.). It might be worth while to apply the calculations of Sutherland and others to various aquatic environments, *i.e.*, deep sea water at a temperature near zero would have a molecular constitution similar to water at 100° for the large trihydrol content determined by the low temperature would be dissociated by pressure. For every atmosphere of pressure 0.00017 gram of liquid ice is dissociated at 0°C. and 0.0001 gram per atmosphere at 100° (Sutherland, 1900, p. 469). However, space forbids us from extending these speculations in the present review.

Looking back over the long list of interesting publications concerning the molecular constitution of water it is indeed surprising that the subject has been so sadly neglected in textbooks of physical chemistry. Even the important volume of Henderson (1927) dealing largely with the fitness of water for living organisms, makes no mention of water polymers. Henderson deals with the high specific heat of water as a unique and biologically important property but this remains unintelligible unless it is realized that the specific heat of water is largely made up of the heat of dissociation of trihydrol. From a consideration of the many forgotten properties of hydrogen oxide discussed by the authors whose papers have been summarized, it is clear that a fruitful field awaits further investigations of the biological significance of water. The present review is not complete—for example, we can but mention such important papers as that of Coolidge (1933) on the quantum mechanics of the

water molecule, which do not deal directly with association—but we have selected typical papers dealing with each important aspect of the problem. If our researches on the biological properties of types of water stand the test of further criticisms, a more extensive review will be prepared.

SUMMARY

Experiments by the senior author (T. C. B.) indicated that condensed steam water and ice water differ in some way as judged by their effect on *Spirogyra*. A comparable difference was found by the authors in the effect of these types of water on *Euglena*. As this difference may prove to be due to the different molecular complexity of the water samples resulting from a change of state, it was thought advisable to prepare the present paper dealing with all significant investigations on the association of water and the properties which this may influence. The more important papers on "trihydrol" covering the period 1879 to 1933 are reviewed and a few other important contributions dealing with related water problems are briefly summarized. It is significant to note that the most recent comprehensive analysis of water structure (Rao, 1934) supports the old mono-, di- and trihydrol hypothesis. Additional data are given relative to the *Euglena* experiments and the freezing times of ice and steam water. It is concluded that all water contains "trihydrol" aggregates whose concentration varies with temperature and to a less extent with pressure and the concentration of solutes, and that there may exist a considerable time factor in the attainment of association equilibrium under certain conditions. Further, it is pointed out that the molecular complexity of water has well recog-

nized biological consequences such as the stability at ordinary temperatures of this compound of elements with such low boiling points as H and O; and the hypothesis is considered that the concentration of polymers in ice water may exert new and little known effects on certain types of living cells.

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HEAVY WATER AND METABOLISM

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LEWIS (1) first published his finding of the completely inhibitive effect of pure heavy water (D_2O) upon the germination of tobacco seeds, and the retardation of the same process by only 50 per cent heavy water; he followed this article with an account (2) of similar effects upon the growth of yeast and bacteria, and the fatal effects upon flatworms immersed in the heavy isotope. He cites the work of Pacsu (3) who found that 100 per cent heavy water retarded the normal rate of fermentation of sugar by yeast by about 89 per cent, while 60 per cent D_2O retarded the process by only about 37.5 per cent. Lewis' work on the mouse showed that this rodent suffered various deleterious effects and manifested great thirst, when allowed to drink only heavy water. Taylor, Swingle, Eyring, and Frost (4) had shown that flatworms, tadpoles, small fishes, and certain Protozoa were killed by immersion in 92 per cent heavy water for certain intervals, but that 30 per cent showed no lethal effects.

Heavy water, while not strongly toxic, exerts at high concentrations probably universal deleterious effects upon living organisms, just as do certain vitamins, hormones, and drugs. Like such substances also, heavy water in very dilute concentration exerts little or no effect differentiable from those of ordinary water, while certain intermediate concentrations appear to be highly stimulative to growth.

Thus Macht and Davis (5), using a sample of water containing only 1 part D_2O in 2000 parts H_2O found that this solution, compared with ordinary water, produced

only a slight retardation of the germination of *Lupinus* seedlings, whether salts were added or not, no apparent differences in the fermentation of sucrose by yeast, no changes in the physiological behavior of injected mice or of immersed goldfish, or in the rhythmic behavior or response to drugs by surviving smooth muscle from various sources, and no changes in the blood pressure or respiration of injected cats. On the other hand, Barnes (6, 7) found that heavy water of about the same concentration increased the longevity of *Spirogyra* filaments, and led to a decrease of abscission, as compared with controls in distilled water, whether various salts or buffers had been added to each medium or not. Similarly Richards (8) using the same solution but studying a yeast (*Saccharomyces cerevisiae*) instead of a green alga, found that this fungus when grown in the heavier water produced a larger total volume of cells by 20 per cent, had a larger mean cell size by 3 per cent, and showed a dry weight 26 per cent greater than the controls cultured in ordinary water. A greater variation in individual cell size was found in the yeast cultured in the heavier water.

According to Barnes and Larson (9), *Oscillatoria* spread more extensively in the above fraction of isotope water than in ordinary water. They suggest that the observed heavy water effects may be due to its influence on enzymes; pancreatic amylase in the D_2O solution for 24 hours was less active than were controls in ordinary water. A zymase, exposed for 66 hours to the heavy isotope showed 10

per cent less CO_2 production than controls in ordinary water.

Both Barnes and Richards, who found unmistakable effects, used approximately the same concentration of solution as did Macht and Davis (specific gravities of 1.000061 vs. 1.000060 respectively) but apparently worked with more sensitive material, and utilized more delicate means of observation. Mayer (10) employing water containing 1 part deuterium to 213 parts protium (more than nine times as strong as that used by Barnes, Richards, and Macht and Davis) found that a nutrient solution made of this supported the development of mycellial felts of *Aspergillus* sp. which reached a weight (dry) sixteen times as great as that of controls grown under the same conditions, but using ordinary water as solvent. He also found several indications of marked stimulation by D_2O , with diminished fruiting, and irregular and localized distribution of spores on the surface.

Hevesy and Hofer (11) observed that goldfish (*Carassius auratus*) behaved normally in 0.5 mol per cent D_2O . They present evidence to show that the heavy isotope was readily taken up by the animals' tissues, and as readily given up again when the fish were returned to ordinary water.

Finally, Washburn and Smith (12) have shown that the growing willow performs an isotopic fractionation of combined hydrogen during synthesis of organic compounds, retaining in the sap and woody tissues greater amounts of D_2O than normally exist in water. No preferential absorption occurs on the part of the root membranes.

The biological properties of heavy water not only challenge the general physiologist, but must capture the interest of those engaged in studies of such composite sciences as ecology, oceanography, agriculture, and medicine.

Since it is known that brine ponds, salt lakes, and oceans have, presumably in the process of fractional evaporation, accumulated a greater-than-normal content of heavy water¹ would it not be of considerable value to know whether certain halophilic animals, plants, and bacteria found in such localities might have a tolerance, or even a need, for higher concentrations of heavy water² as they do for higher concentrations of dissolved salts?

Lewis (2) makes the suggestion that perhaps certain organisms may have an actual need for heavy water, and that experiments be made to analyze for both waters the tissues of plants and animals maintained in media of varying isotopic composition.

Certain it is that heavy water exerts very different effects upon the metabolism of organisms, according to its concentra-

¹ Bleakney and Gould (13) working at Princeton, have concluded that their closest approximation to the actual amount of D_2 in hydrogen from rain water is 1:5000.

Gillfillan (14) found a difference of 2.3 parts per million between the densities of carefully prepared distillates from sea-water (from the surface or from great depths) and distillates from laboratory tap water. He takes the isotopic identity of sea-water distillates from all depths as signifying that the sea has not reached equilibrium, and that the observed differences in D_2O content between sea and land waters are perhaps due to the differences in distillation rates of the two isotopes.

² Dole (15) determined the densities of distillates obtained from samples of water taken from the Atlantic Ocean, the Dead Sea, Great Salt Lake, and from hydrated mineral razorite, and found the values to be greater than those for fresh water by several parts per million, indicating a naturally occurring isotopic fractionation, presumably by distillation. Dole suggests, on the basis of others' work, that living organisms may select protium in preference to deuterium, but points out that the heavy isotope may be concentrated physiologically. He cites the work of Washburn and Smith (op. cit.) and reports an excess of deuterium in honey, benzene, and a kerosene over that in ordinary water by 4, 7, and 8 parts per million respectively. He suggests that such data from petroleum distillates may shed light upon the origin of petroleum.

tion. Experimentation on the relative concentrations of both waters for optimal growth in certain plants and animals of commerce would have a manifestly valuable application. Such experiments are probably in progress.

Hackh and Westling (16) recently suggested that heavy water, boiling at 101.42°C . as contrasted with the boiling point of ordinary water, may therefore evaporate more slowly from the human body than does the latter, and gradually thus becoming accumulated, may be responsible for the various retardations and inhibitions in protoplasmic activity characteristic of senescence.

The work of Washburn and Smith indicates some kind of selective retention of heavy water by the young willow, but if such a phenomenon were also found to be true for animals including humans, it would seem a rather colossal feat to attribute to differential evaporation alone, in view of the small differences in vapor pressure of the two water isotopes, and the numerous and intricate aspects of water metabolism, including the paths of water elimination, any of which might conceivably act somewhat selectively. Also, the mechanism proposed by Hackh and Westling could not account for senescence in marine and other aquatic animals.

The investigations of Washburn and Smith, and the speculative communication of Hackh and Westling are of help, however, in suggesting certain possibilities in the realm of medicine. It is well known that three types of animal tissue having the highest water content (excepting the body fluid and certain highly vascularized organs) are embryonic, germinal (ovaries, testes) and neoplastic (cancerous growths). Cell division is more rapid in the first two classes, and often in the last class, than in normal, adult somatic tissue.

While in the former three kinds, growth (addition of new cells) is taking place, in the latter, merely maintenance, or cell replacement is occurring. With fetal development, birth, adolescence and maturity ripening into age, the total water content of the body undergoes a gradual decrease from about 94 per cent in a three-months human fetus, 66–69 per cent at birth, to about 58 per cent in adult life, lessening continually with age (17, 18). Reproductive functions also lessen with the onset of senility. The incidence of cancer is far greater in the elderly than in youth or in adults at their prime.

If, during a gradual decrease in the total water content of aging animals, some degree of selective retention of heavy water occurred, somewhat comparable to the case of the young willow tree, by whatever mechanisms in operation, might not this accumulation reach concentrations, general or localized, sufficient to stimulate the maximum production of neoplastic cells (just as certain ranges of heavy water concentrations stimulate the growth of algal and fungal cells), given the necessary accessory determinants? That certain accessory stimulants are present in neoplasmodgenesis is indicated by the ease of excising or otherwise destroying incipient growths, the transplantability of certain tumors (19, 20), and the chemical inhibition (21) of "takes" in transplants. That, given favorable conditions for the occurrence of rapidly growing masses of cancerous tissue, heavy water at certain concentrations might act as an effective stimulant to the growth of such cells is suggested by reviewing the work of certain authors cited.

To Lewis' proposal that the relative proportions of the two hydrogen isotopes be determined in the tissues of organisms provided with heavy water at various

concentrations is added the suggestion that both normal and cancerous tissues of animals throughout the life span might be so analyzed with a view to throwing light on the question of a possible rôle played by heavy water in the stimulation of such growths.

ADDENDA

Since the preparation of this review, several articles have appeared. These should be mentioned in order to bring the review up to date.

H. S. Taylor (22), in a brief review of the chemical, physical, and biological work with heavy hydrogen at Princeton, mentions the initiation of work in one line of investigation which has been independently suggested in this present paper, concerning the effects of heavy water upon cancer cells. Taylor also mentions experiments by Dr. J. Pace which show that high concentrations of D_2O depress the catalytic decomposition of hydrogen peroxide by blood catalase.

Stewart and Holcomb (23) investigating the possible biological separation of heavy water, carefully fractionated and refractionated tap water, water from cow's milk, and from cow's urine, comparing the D_2O concentration in the distillates using the most recent and careful methods. They found no differences in the water from these various sources, but admit that further work must be done, especially with reference to heavy hydrogen in milk, urine, and other body fluids. The isotopic composition of respired water, water of perspiration, and the various body fluids still remains to be investigated, and attention should be paid to the question of alterations in composition with changes in physiological states such as aging and various pathological conditions.

Harvey (24), found that heavy water (85-95 per cent) did not prevent the luminescence of dried *Cypridina*, nor affect luminescence in a fresh water luminous bacterium, but diminished luminescence in a marine form, retarded the growth of luminous bacteria, killed a number of protozoa and rotifers, and did not kill bacteria nor irreversibly injure *Euglena*. The heavy isotope penetrates *Elodea* cells and slowly

retards protoplasmic cyclosis. Harvey concludes, having eliminated the possible presence of traces of toxic impurities such as peroxide and nitrogen oxides, and in consideration of the slow and often reversible effects of heavy water, that "its action may be likened to that of a generally unfavorable environment leading to progressive changes in the cell." He suggests that the observed changes may result from "differential effects on the rate of biochemical reactions, which ordinarily proceed at a certain definite rate in relation to each other."

Harvey and Taylor (25) found, using the Warburg respirometer, that marine luminous bacteria, kept in salt and peptone cultures containing heavy water, underwent a decrease in respiration rate, the higher concentrations exerting the greatest effects. Luminescence was markedly decreased in 86 and 63 per cent D_2O . The writers noticed a similar reduction of respiration in a fresh water form, *Vibrio phosphorescens*, without appreciable reduction in luminescence.

Barnes (26), who is one of the chief students of the physiological effects of heavy water and the various hydrols (H_2O , $(H_2O)_2$, $(H_2O)_3$) upon single-celled organisms in particular has found that heavy water of low concentration (density of 1.000061) increased the rate of division of *Euglena* by more than 15 per cent, as compared with organisms kept in ordinary water, and that there were 2.3 times as many of the active forms in the water containing the heavy isotope as in the ordinary water. He suggests that D_2O in small quantities may be an essential part of living systems, and that perhaps in the case of *Sperogrya* and *Euglena* in hypotonic solutions, the reduction in enzymic hydrolysis may prolong cell life and thus allow opportunity for the increased cell division observed.

Woodard and Chesley (27) reported that gelatin absorbed in a given time 20 per cent less heavy water (from a 90 per cent D_2O solution) than did equal amounts in ordinary water. They stressed the importance of water absorption in life processes, and believe that their experiments with gelatin indicate a possible mechanism of the retardation of growth of plants or animals living in high concentrations of the heavy water isotope.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of THE QUARTERLY REVIEW OF BIOLOGY, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

BRIEF NOTICES

EVOLUTION

MAN'S PLACE AMONG THE ANTHROPOIDS. *Three Lectures on the Evolution of Man from the Lower Vertebrates.*

By William K. Gregory. Oxford University Press, New York. \$2.50. 8 $\frac{3}{4}$ x 5 $\frac{3}{8}$; vi + 119 + 5 plates; 1934.

These three lectures, delivered at University College and Oxford University, represent Professor Gregory's rejoinder to Professor Wood Jones' *Man's Place Among the Mammals* (reviewed in the QUARTERLY, Vol. 5, page 370). Professor Gregory, marshalling a vast amount of authoritative evidence, attacks the latter's thesis that man has been derived not from any early ape at all, but from a far older and long extinct branch of the Primates; that is, that man is distantly related to the spectral tarsier of Borneo and the Philippines. Taking sides in this controversy seems neither judicious nor necessary.



MARINE MAMMALS. *Contributions to Palaeontology. Carnegie Institution of Washington Publication No. 447.*

By Earl L. Packard, Remington Kellogg, and Ernst Huber. Carnegie Institution of Washington, D. C. \$4.00 (paper); \$5.00 (cloth). 10 x 6 $\frac{1}{2}$; 136 + 8 plates; 1934.

Four papers are included in this publication of the Carnegie Institution of Washington: A New Cetothere from the Miocene Astoria Formation of Newport,

Oregon, by Earl L. Packard and Remington Kellogg; The Patagonian Fossil Whalebone Whale, *Cetotherium moreni* (Lydekker), by Remington Kellogg; A New Cetothere from the Modelo Formation at Los Angeles, California, by Remington Kellogg; Anatomical Notes on Pinnipedia and Cetacea, by Ernst Huber.

In the first paper in the series will be found a partial list of fossil mollusks from the Astoria formation (Middle Miocene) of Lincoln County, Oregon; a list of specimens of fossil marine mammals obtained from the Tertiary of the Newport region; and a map of a portion of the Oregon coast showing localities of fossil marine mammals. Measurements of all bones described in the first three papers are arranged in tabular form in the texts. The material in the last paper in the group has been arranged by Professor A. Brazier Howell from manuscripts and notes left by the late Ernst Huber.



CONTRIBUTIONS TO PALAEONTOLOGY. *Papers Concerning the Palaeontology of California, Arizona, and Idaho. Carnegie Institution of Washington Publication No. 440.*

Carnegie Institution of Washington, D. C. \$2.25 (paper); \$3.25 (cloth). 10 x 6 $\frac{1}{2}$; 135 + 28 plates; 1934.

The detailed data in these papers are carefully tabulated and subdivided. Each article has a content outline following its

title. The volume is well supplemented throughout with text figures and plate illustrations. It contains the following papers: Tertiary mammals from the auriferous gravels near Columbia, California, by John C. Merriam and Chester Stock; Notes on the geologic section near Columbia, California, with special reference to the occurrence of fossils in the auriferous gravels, by George D. Louderback; Perissodactyla from the Sespe of the Las Posas Hills, California, by Chester Stock; Carnivora from the Sespe of the Las Posas Hills, California, by Chester Stock; Anchitheriine Horses from the *Merychippus* Zone of the North Coalinga District, California, by Francis D. Bode; Pleistocene mammalian fauna from the Carpinteria asphalt, by Robert W. Wilson; The Coconino sandstone—its history and origin, by Edwin D. McKee; A rodent fauna from later Cenozoic beds of Southwestern Idaho, by Robert W. Wilson.



THE EVOLUTION OF THE VERTEBRAL COLUMN. *A Contribution to the Study of Vertebrate Phylogeny.*

By H. F. Gadow. Edited by J. F. Gaskell and H. L. H. H. Green. University Press, Cambridge; The Macmillan Co., New York. \$6.75. 9½ x 6; xiv + 356; 1933.

The aim of this book is "to put together the evidence of the various lines of development of the vertebrae as a guide to the general morphological scheme of vertebrate evolution." For over forty years the author, late Strickland Curator and Reader in Vertebrate Morphology in the University of Cambridge, had been interested in the morphological problems of the vertebrate phylum. At the time of his death he had accumulated much of the material for the present volume. The editors, J. F. Gaskell and H. L. H. H. Green, are responsible for the final arrangement of the latter part of the book, as well as for certain other necessary changes which the manuscript indicated. They are also responsible for the selection of the many illustrations.

A lengthy bibliography and an index are included in the volume.



SCHIMPANSISCH, URMONGOLISCH, INDOGERMANISCH.

By Georg Schwidetzky. Deutscher Verlag, Leipzig. 5 marks. 8½ x 5½; 94; 1933 (paper).

In this interesting but not altogether convincing little book the author attempts to derive an evolutionary relationship between the chimpanzee and man, by a philological comparison of the chimpanzee "language" with that of various tribes of the Mongolian and Indo-Germanic races. He compares words used by man with those of the Yerkes-Learned "word list" of the chimpanzee. The book is equipped with an extensive bibliography and an index.



PLANT LIFE THROUGH THE AGES. *A Geological and Botanical Retrospect. Second Edition.*

By A. C. Seward. The University Press, Cambridge; The Macmillan Co., New York. \$8.00. 9 x 6; xxi + 603; 1933.

Mention has already been made in these pages of the first edition of this volume which was published in 1931 (Volume 7, page 101). The second edition is unchanged except for a few alterations and corrections in the text and the addition of a short list of references.



GENETICS

HEREDITY AND THE SOCIAL PROBLEM GROUP. Volume I.

By E. J. Lidbetter. Longmans, Green and Co., New York. \$7.50. 9½ x 7½; 159 + 26 folding charts; 1933.

For many years the author, aided by the English Eugenics Society, has conducted an investigation on individuals residing in a Poor Law district of East London, who normally resort to public assistance. The scope of the study is: (1) To ascertain the

measure of family chargeability, and, as far as possible, reduce the results to pedigree form. (2) To measure the periods of chargeability against the periods of independent support. (3) To ascertain the age of onset and the incidence of repetition in recurrent cases. (4) To secure records of fertility and survival in the several classes. (5) Generally to compare the ascertained family chargeability with individual chargeability.

This volume is limited to a report of part of the data and consists of twenty-six pedigrees with statistical and biographical notes. A survey of the charts shows that the introductory observations of the author are well founded. There is a very high degree of assortative mating and frequent appearance in each generation of mental and physical defectives.

It can be foreseen that the conclusions will be of interest and importance.



ENFANCE ET HÉRÉDITÉ.

By A. Lesage. Masson et Cie, Paris. 20 francs. $7\frac{1}{8} \times 5\frac{1}{4}$; 104 + 10 plates; 1933 (paper).

A brief summary of clinical notes on hereditary taints observed in infants, in particular cranial malformations and signs of arthritic diathesis. The author desires to emphasize the fact that many obscure ailments are not to be attributed to external causes but to faulty heredity, and therapy should be directed accordingly.



GENERAL BIOLOGY

ADAPTATION. ÉCOLOGIE ET BIOGÉOLOGIQUE. *Actualités Scientifiques et Industrielles* 103. *Exposés de Biologie Écologique*.

By Marcel Prenant. Hermann et Cie, Paris. 15 francs. $10 \times 6\frac{1}{2}$; 60; 1934 (paper).

The central idea of this brilliant and penetrating study is the necessity for the physiological analysis of the environment if the phenomenon of adaptation—which is essentially the correlation between organism and environment—is to be understood. The discussion begins with a chapter on

the tremendous power of living material to expand in space and time. As the author truly says this is the essential fact of adaptation, and indeed the central idea of biology. This is followed by a chapter on the great complexity of the physical environment, in which it is emphasized that, for example, the limits of viability of an organism relative to a particular environmental agent such as temperature, as determined by the physiologist in the laboratory, rarely agree with those found by the ecologist in nature. The next chapter discusses the interaction of organisms in nature, on the basis particularly of the work on experimental populations of Pearl with *Drosophila*, Park with *Triebolium*, and the mathematical analyses of Lotka and Volterra. A final chapter on biocenosis and ecology argues for the reality of true association of living things, with concomitant biological interactions. Professor Prenant reaches the general conclusion that the relation between organism and environment cannot be completely and realistically analyzed in physico-chemical terms alone. There are four short appendices and a bibliography of seven pages.

Altogether this little book is a contribution to theoretical and philosophical biology of the very first rank of importance.



THE JUNGLE IN SUNLIGHT AND SHADOW.

By F. W. Champion. Charles Scribner's Sons, New York. \$7.50. $10 \times 7\frac{1}{4}$; xvi + 270 + 95 plates; 1934.

Of the making of books about the jungle and its inhabitants there is no sign of anything approaching an end. But this particular one will stand for a long time in a class by itself. In the first place the author is a trained zoologist in the Indian Forest Service, and writes an intelligent and charming text, informed with an immense knowledge of the jungle and its denizens. In the second place his illustrations, of which there are some ninety-five full page half-tone plates, are simply and literally superb. And the book is not, like so many in its general class, merely about elephants and/or tigers. Mr.

Champion shows us a wide range of rarer animals in his zoo. His chapters on the ratel or honey-badger and the pangolin make definite contributions to knowledge. Strange creatures both are.

No student of ecology or animal behavior should miss this book. And we suppose all sportsmen will want it on their library shelves, though one can but wonder what a hunter's reaction would be if he were really to grasp Mr. Champion's viewpoint about wild life. For he never harms or kills an animal. His sympathy with living nature is without limits or bounds. Yet he is no sentimentalist, and his discussion of the balance of nature is one of the most realistic and penetrating to be found anywhere in biological literature.

There is a detailed index and a brief glossary of Indian vernacular terms.



CONTRIBUTION À L'ÉTUDE DU PEUPLEMENT ZOOLOGIQUE ET BOTANIQUE DES ÎLES DU PACIFIQUE. *Mémoires de la Société de Biogéographie* IV.

By L. Berland, J. Berlioz, E. H. Bryan, E. Cheesman, L. Joleaud, L. Chopard, L. Germain, A. Guillaumin, K. Holdhaus, Mumford and Adamson, P. Rivet, L. Seurat, C. Skottsberg, E. Topsent, C. Valaux. *Paul Lechevalier et Fils, Paris.* 70 francs. 10 x 6½; 288; 1934 (paper).

This is a collection of sixteen papers by as many authors on plant and animal distribution on the islands of the Pacific Ocean. Four papers deal specifically with insects, three with vascular plants, and there are single papers on sponges, spiders, birds, paleontology, and human ethnology. Other papers deal with the flora and fauna of certain archipelagos. It appears from these papers that serious attempts are well under way to obtain systematic and representative collections of the flora and fauna of the smaller islands of the Pacific in place of the casual and sporadic collections hitherto available. Three of the papers are in English and one is in German. All of the articles are accompanied by bibliographies and a few of them by maps.

NATURE CHATS. *A Year Out-of-Doors.*

By John H. Furbay. *Science Press Printing Co., Lancaster, Pa.* \$1.75. 8½ x 5½; xv + 255; 1933.

Unless modern youth is considerably less "hard-boiled" than it claims to be, this volume will not do much to increase interest in nature study. There is more poetry than nature to the book. There are nearly fifty illustrations, all but one or two of which are pen and ink drawings. They do nothing to redeem the book.

Wasps do not store any food. Some honey is made for feeding the young wasps, but it is never stored in the nest. They seem to live only for the pure joy of living. They remind us of the words of Burroughs who said that the game of life itself is worth all the trouble and pain it takes to play it. They work all summer building a nest which they will never live in; yet how happy they seem to be while doing it. And, after all, our own lives are not very different.



LES PROBLÈMES DE L'HÉRÉDITÉ ET DU SEXE. *Bibliothèque Générale Illustrée.* 23.

By Jean Rostand. *Les Éditions Rieder, Paris.* 20 francs (paper); 25 francs (cloth). 8 x 6; 92 + 60 plates; 1933.

M. Rostand writes well and lucidly on Mendelism, the chromosomes, sex, parthenogenesis, mutation, influence of environment on organisms, and eugenics, making this one of the best brief accounts, designed for the general reader, we have seen on these subjects. The author has provided a short bibliography of general treatises, and sixty excellent photographic plates.



LA CELLULE ET LES PROTOZOAIRES. *Actualités Scientifiques et Industrielles* 106. *Leçons de Zoologie et Biologie Générale.*

By Georges Bohn. *Hermann et Cie, Paris.* 18 francs. 10 x 6½; 121; 1934 (paper).

REPRODUCTION. SEXUALITÉ. HÉRÉDITÉ. *Actualités Scientifiques et Industrielles* 120. *Leçons de Zoologie et Biologie Générale.*

By Georges Bohn. *Hermann et Cie, Paris.* 15 francs. 10 x 6½; 89; 1934 (paper).

These two brochures constitute the first two numbers of a series of five designed for the use of students of general biology and zoology. The first treats the cell and

protozoa; the second embryonic mechanisms, sexuality and genetics. They are well written, and the illustrations and printing are good.



IDEEN UND IDEALE DER BIOLOGISCHEN ERKENNTNIS. *Beiträge zur Theorie und Geschichte der biologischen Ideologien.*

By Adolf Meyer. Johann Ambrosius Barth, Leipzig. 9.75 marks. $9\frac{1}{2}$ x $6\frac{1}{4}$; xiii + 202; 1934 (paper).

[An extended review of this book will appear in a later number. EDITOR.]



CONFÉRENCES FAITES AU LABORATOIRE DE MICROBIOLOGIE DE LA FACULTÉ DE PHARMACIE DE NANCY. *Fascicule VI.*

Laboratoire de Microbiologie de la Faculté de Pharmacie, Nancy. $9\frac{1}{2}$ x $6\frac{1}{4}$; 37; 1934 (paper).



HUMAN BIOLOGY

REMINISCENCES (MAINLY PERSONAL) OF WILLIAM GRAHAM SUMNER.

By A. G. Keller. Yale University Press, New Haven, Conn. \$2.00. $8\frac{3}{4}$ x 6; 110; 1933.

In an age when the *laissez-faire* viewpoint is moribund—or is it? We shall know better after next November—it might seem that a figure like Sumner had lost his significance. It is true that Roosevelt has repopularized—and incidentally misapplied—his once famous phrase, "The Forgotten Man," but Sumner's Forgotten Man, "the clean, quiet, virtuous, domestic citizen, who pays his debts and his taxes," stands to lose rather than to gain by the New Deal. Yet it is our loss if we forget the strictures of an honest and forthright critic. There is certainly no lack of timeliness in the following passage, for instance:

The government is to give every man a pension, and every man an office, and every man a tax to raise the price of his product, and to clean out every man's creek for him, and to buy all his unsalable property, and to provide him with plenty of currency to pay

his debts, and to educate his children, and to give him the use of a library and a park and a museum and a gallery of pictures. On every side the doors of waste and extravagance stand open; and spend, squander, plunder, and grab are the watchwords. We grumble some about it and talk about the greed of corporations and the power of capital and the wickedness of stock gambling. Yet we elect the legislators who do all this work. Of course, we should never think of blaming ourselves for electing men to represent and govern us, who, if I may use a slang expression, give us away? What man ever blamed himself for his misfortune? We groan about monopolies and talk about more laws to prevent the wrongs done by chartered corporations. Who made the charters? Our representatives. Who elected such representatives? We did. How can we get bad law-makers to make a law which shall prevent bad law-makers from making a bad law? That is, really, what we are trying to do. If we are a free, self-governing people, all our misfortunes come right home to ourselves and we can blame nobody else. Is any one astonished to find that men are greedy, whether they are incorporated or not? Is it a revelation to find that we need, in our civil affairs, to devise guarantees against selfishness, rapacity, and fraud? I have ventured to affirm that government has never had to deal with anything else.

The writer of these reminiscences was a student of Sumner's and later his colleague and successor. A systematic biography of Sumner having been already given to us by Starr, Keller aims rather to perpetuate Sumner's personality, his influence in clearing his students' minds of cant, the personal kindliness that lay behind a somewhat forbidding exterior. One characteristic story is of his address to a convention of school teachers which was giving its chief attention to questions of pedagogical methodology.

When I was in college, I knew a fellow who got all worked up over *how* to study. He had lots of theories. He tried it sitting down, lying down, standing up, standing on one leg, and so on. When the examination came, he flunked and was dropped from college. He hadn't studied at all. He had spent his time getting ready to do something. He didn't know anything.



... SOMETHING NEW OUT OF AFRICA.

By HW. Pisman Publishing Corp., New York. \$5.00. $9\frac{1}{2}$ x $7\frac{1}{8}$; xx + 208 + 4 folding maps; 1934.

We really do have something new in HW's account of his travels along the air routes of Africa. Having commanded the Squadron of the Royal Air Force in the Sudan

he is thoroughly versed in the art of flying in this land and not only for the prospective pilot but for the air traveler as well his report of conditions and of the technique of dealing with them from a flyer's viewpoint is invaluable.

Over one hundred excellent photographs, many taken from the air, depict Egyptian pyramids and temples, Africans in their native costume or rather lack of costume, and herds of wild animals in their natural habitat. Some of the latter are striking illustrations of the blending of the animals with the landscape. There are several examples of Abyssinian art, one of them being a colored reproduction of a pictorial narration of the story of the Queen of Sheba and how the wicked King Solomon "done her wrong."

It is interesting to learn that the noise of an airplane at a reasonable height does not alarm the wild animals to any great extent. Maps keep us informed of our whereabouts and, since use of them does not involve a complicated system of folding and unfolding, we really use them with ease and interest. The author informs us that at last the airplane can be the main instrument in solving a difficult and serious problem: the smuggling of slaves and other contraband. A boat hidden behind a reef is not hidden long if one can search from above. The method of "tracking down" the boats and the inspection process reads like a new adventure story.

HW is thoroughly in earnest about the importance of developing air transportation in a continent which, he feels, needs foreign intervention but so far gains slowly under it. This is due largely to the different climatic conditions, to the different policies of the various countries in their colonies, and to the natives themselves, who are slow to desire progress, scattered and impossible to unite, being bound often by tribal superstitions that go back for hundreds of years.

Gordon and Kitchener return to us in the vivid descriptions and excellent photographs of Khartoum and of the now deserted city of Suakin. HW has given us an extremely readable travel story. He has not overstressed the distinguished passengers, such as the Prince of Wales

and the King of the Belgians, who have flown with him, but has given a modest and appropriate tribute to them, remembering that this book is on Africa and what "air mindedness" has done and can do for the continent.



FIVE FUR TRADERS OF THE NORTHWEST.
Being the Narrative of Peter Pond and the Diaries of John Macdonell, Archibald N. McLeod, Hugh Faries, and Thomas Connor.
Edited by Charles M. Gates. University of Minnesota Press, Minneapolis. \$3.50.

8½ x 5½; vii + 298; 1933.

Peter Pond, the author of the first of these documents, was an adventurous Yankee of the eighteenth century who began his career as a provincial trooper in the French and Indian wars and took part in Abercromby's disastrous expedition against Ticonderoga. About 1765 he established himself as a trader at Detroit and for more than twenty years was engaged in trading and exploration in the Northwest. Much of his narrative was unfortunately destroyed as waste paper; the greater part of what remains describes his explorations in the Upper Mississippi valley in the years 1773-1775. The following account of the mourning customs of the Fox Indians illustrates both his libertarian spelling and the vividness of his descriptions:

We asended that River til we Cam to a High Pece of Ground whare that Nation yous to Entar thare Dead when thay Lived in that Part. We stopt hear awhile finding Sum of that Nation on the Spot Who Came thare to Pay thare Respect to thare Departed frend. Thay Had a small Cag of Rum and sat around the grave. Thay fild thar Callemeat [Calumet] and Began thar saremony By Pinting the Stem of the Pipe upward—then givinge it a turn in thare and then toward ye head of the Grav—then East & West, North & South after which thay smoaked it out and fild it agane & Lade [it] By—then thay took Sum Rum out of the Cag in a Small Bark Vessel and Poured it on the Head of the Grave By way of givinge it to thar Departed Brother—then thay all Drank themselves—Lit the Pipe and seemed to Enjoie themselves Veray well. Thay Repeated this till the Sperit Began to Operate and thare harts Began to Soffen. Then thay Began to Sing a Song of two But at the End of Every Song thay Soffened the Clay. After Sumtime Had Relapst the Cag had Bin Blead often. Thay Began to Repete the Satisfaction thay had with that friend while he was with them and

How fond he was of his frends While he Could Git a Cag of Rum and how thay youst to Injoy it togeth-
 er. They Amused themselves in this manner til thay all fell a Crying and a woful Nois thay Mad for a While til thay thought Wisely that thay Could Not Bring him Back and it would Not Due to Greeve two much—that an application to the Cag was the Best Way to Dround Sorrow & Wash away Greefe for the Moshun was soon Put in Execution and all Began to be Marey as a Party Could Bea. Thay Continued til Near Nite. Rite Wen thay Ware More than Half Drunk the men began to aproach the females and Chat frelay and apearantley friendley. At Lengh thay Began to Lean on Each other, Kis & apeared Verey amaras. . . . I Could Observe Clearley this Business was first Pusht on by the Women who made thare visit to the Dead a Verey pleasing one in thare Way. One of them who was Quit Drunk, as I was By [my] Self Seating on the Ground observing thare Saremones, Cam to me and askt me to take a Share in her Bountey. . . . But I thought it was time to Quit.

At this time Pond was an independent trader; later he took part in organizing the Northwest Company of Montreal, of which the four diarists of this volume were partners or clerks. Macdonell's diary gives a narrative of the journey along the main thoroughfare to the Northwest: from Montreal by the Ottawa River and Lake Nipissing to Lake Superior and thence by the Lake of the Woods to Lake Winnipeg. McLeod's diary describes the daily life at a post on the upper Assiniboine, Faries' at the Rainy Lake post near the Lake of the Woods, and Connor's at one in the St. Croix valley in what is now eastern Minnesota.

The fur trader had to be a tough baby. A weakling would have had little success in collecting the debts which the Indian hunters owed him, circumventing his rival traders, keeping his hunters on their job of supplying the post with meat, and disciplining or sometimes defending his post against "drunk and troublesome" Indians.

The University of Minnesota and the Minnesota Society of the Colonial Dames of America may well feel proud of this scholarly and beautifully printed volume. If some other patriotic societies would confine their activities to such worthy enterprises as this they might come to be regarded as useful organizations rather than as public nuisances.

ETHICS AND MORAL TOLERANCE.

By Arthur K. Rogers. *The Macmillan Co., New York.* \$2.50. 7½ x 5½; v + 323; 1934.

This book is addressed to a generation for which the traditional sanctions have lost their force. The problem therefore arises: should each man do what is right in his own eyes, so far as this does not trespass too radically on the well being of others, and concede a similar privilege to everyone else, or is there a more public hierarchy of values by which a man's acts may be assessed? From his analysis of the nature of values Professor Rogers concludes that they consist ultimately in the individual sentiment of approval or disapproval. Yet this conclusion need not necessarily imply our first alternative. The general likeness of human nature furnishes a basis, not for rigid moral criteria, but for "a somewhat indeterminate and plastic goal which exercises an emotional compulsion." We cannot profitably argue with the tiger on ethical subjects; he is what he is, and any condemnation of his lack of our sentiments is irrelevant. Nor can we argue with the tiger in human form; only on the supposition "that a man's present judgment does not exhaust his potential capacities of insight, and that in proportion as this genuine nature comes to light his ways of judging and of feeling may be expected to approximate to ours" have we the right to indulge our moral feelings. This is not a doctrine which encourages moral zealotry but rather the attempt to understand the other fellow's viewpoint, even though finally we may not agree with him.

The man who indulges indiscriminately in moral indignation and who hugs his moral antipathies to his bosom as a proof of his finer sensibilities is on the road to developing qualities of doubtful social merit; the hatred of injustice—a thing quite indispensable in morality—is likely to turn sour and become an animosity toward human beings who outrage our sensibilities or flout our prejudices. Like any other natural feeling indignation must be disciplined before it can become a virtue, and a part of this discipline will consist in shunting it from our human fellow to the obnoxious qualities which, though they may fill our eye for the moment, are certainly not the whole of him.

THE CHINESE. *Their History and Culture. Volumes I and II.*

By Kenneth S. Latourette. *The Macmillan Co., New York.* \$7.50 per set. 8½ x 5½; Vol. I, xiv + 506; Vol. II, 389 + folding map; 1934.

These two volumes belong with the group of the most important recent books on China. The writer brings vividly before the reader China's brilliant past and the causes of her present chaotic state. A great race, more nearly uniform than India, Europe or America, until recently separated from the rest of the world by barriers of mountain, desert and water, China developed her political and social institutions, her philosophy and economic life free from foreign influences. For over 2,000 years the political framework of China was little changed. Furthermore she was the great teacher of her immediate neighbors, especially the Koreans and the Japanese. Within the last century this great civilization has been in the process of change. In Volume I the author discusses the geography and natural resources of China and gives a summary of the nation's history from the beginning to the present. Volume II deals with population and the main phases of the culture and institutions of the country as they developed before the coming of the European and the modification that European culture imposed upon them. A bibliography is appended to each chapter. A section is included giving proper names and Chinese words used in the text and their corresponding Chinese characters. There is a carefully prepared index and a large map is attached to the final page.



IBN SA'UD. *The Puritan King of Arabia.*

By Kenneth Williams. *Jonathan Cape, London.* 8s. 6d. net. 8 x 5½; 299; 1933. His Majesty King Abdul Aziz ibn Abdul Rahman ibn Faisal as Sa'ud, more handily known as Ibn Sa'ud, is without question one of the very greatest figures, if not in reality quite the greatest, now living in this imperfect world. In the history of Islam he bids fair to rank second only to

the Prophet Muhammad himself. His life story, which is simply, accurately and fairly told in this volume, is a mine of interest for the serious student of human biology.

In exile as a youth, and with nothing but the force of his own character and personality in the way of assets, this Cromwell of Arabia has made himself the absolute sovereign of nearly the whole of that great peninsula, and would undoubtedly by now be ruling the remainder had it not been for the interference of certain of the great powers. In his personal and public life he obeys literally the tenets of the most primitive form of the Islamic religion. But at the same time he employs every device of modern applied science, radio, the airplane, automobiles, etc., to aid him in his job of conquering and ruling. Ruthless as he can be and repeatedly has been, he is as much beloved as feared by his people, as anyone must be who is to rule the Badawin for long. In his dealings with other countries, which have been trying and difficult, he has exhibited a patience and intelligence of the highest order. As a diplomat he stands in the front rank.

The book is quietly and conservatively written, and is well documented and indexed. We recommend it.



MATERNAL MORTALITY AND MORBIDITY. *A Study of Their Problems.*

By J. M. Munro Kerr. *William Wood & Co., Baltimore.* \$8.25. 9½ x 7½; xviii + 382; 1933.

The author of this book has been for many years professor of midwifery in the University of Glasgow and obstetric surgeon in the Glasgow Royal Maternity and Women's Hospital. His purpose in writing this book is to assemble all available information concerning maternal mortality and morbidity that has been contributed by different sections of the medical profession. The material is arranged under four general headings: (1) Causes; (2) Prevention; (3) Service and (4) Organization. Chapter VI on "Maternal morbidity and subsequent disablement" is

contributed by Dr. Donald M'Intyre, and Chapter VII on "Neonatal death and disablement," by Professor G. B. Fleming. In a group of four appendices other phases of the general subject are discussed. It is the author's belief that only by full co-operation of the many different services and agencies concerned with maternal welfare can the present unsatisfactory level (for England and Scotland) of maternal mortality and morbidity be altered.

The volume includes illustrations, a considerable mass of statistical data, a design of a maternity hospital with suggestions for organization and staffing, and an index.



THE DISCOVERERS OF THE FIJI ISLANDS.
Tasman, Cook, Bligh, Wilson, Bellingshausen.

By G. C. Henderson. John Murray, London. 18 shillings net. 9 x 5½; xviii + 324 + 37 plates and charts; 1933.

To the average reader this will be merely an interesting book on discoverers of the Fiji Islands. Only a relatively small number will appreciate the historical importance of the work. Professor Henderson, in order to clear up the doubt which existed concerning the exact discoveries made by different navigators, provided himself with reports, charts and drawings, discoverers' log-books, etc., and made several cruises through the archipelago, tracing out the courses of the different voyages and their various discoveries. The great names in Fiji exploration are:—Tasman, who set sail from Batavia in 1642 and made one of the great voyages of discovery recorded in history; Captain Cook; William Bligh, of *Bounty* fame; James Wilson, with whose voyages in 1797 began the history of Protestant Missions in the South Pacific; and Fabian von Bellingshausen, a Baltic German in the service of the Russian Government, whose journal, which has never been translated into English, contains much of interest concerning the natives of Ono-i-lau. Numerous extracts of the navigators' journals are included in the volume, also copies of their charts. The volume is abundantly illustrated and contains in a

pocket at the end a large map of Fiji showing the tracks of the discoverers. There is an index.



MATERNAL MORTALITY IN NEW YORK CITY. *A Study of All Puerperal Deaths 1930-1932.*

By the New York Academy of Medicine Committee on Public Health Relations; Ransom S. Hooker, Director of the Study. The Commonwealth Fund, New York. \$2.00. 9 x 6; xxi + 290; 1933.

In 1930, with the financial aid of the Commonwealth Fund, a committee of the New York Academy of Medicine courageously undertook to determine the essential causes of the alleged high maternal mortality in the United States. The committee, composed of competent and highly trained obstetricians and public health workers, investigated with the greatest care the pertinent details of 2,041 maternal deaths in New York City. As a result of the most meticulous scrutiny of each case it was concluded that 1,343 fatalities would have been preventable "... if the care of the woman had been proper in all respects." Responsibility for 61 per cent of the preventable deaths was placed upon physicians, for 37 per cent upon the patients themselves, and 2.2 per cent were charged to midwives. The direct and indirect causes of these deaths varied widely, the committee estimating that fully 60 per cent were brought about by "... some incapacity in the attendant; lack of judgment, lack of skill, or careless inattention to the demands of the case." Thirty-one pages of tables included in the appendix indicate the large amount of data collected and it may be hoped that a much more detailed analysis will be made. The book is a classic; it is extremely well written and should be in the library of all persons who are truly interested in public welfare.



THE ABYSSINIAN AT HOME.

By C. H. Walker. The Sheldon Press, London. 7s. 6d. net. 7½ x 5; xii + 220; 1933.

In the preface the author states that "this book is a translation of Amharic notes, which are the statements of natives taken down in their actual speech and pieced together under the appropriate subject so as to read more harmoniously." These notes describe some of the beliefs, ideas and customs regarding religion, personal relations and property. However, there is no indication how deeply these pervade and influence individual action. Religion apparently dominates all phases of life but in somewhat the same detached and formalistic fashion that it affects the people of Southern Europe. Money is an all important factor, the form of reparation for most misdeeds and the means of obtaining justice. Women are considered fickle and therefore are not allowed to take oaths and their promises have no value. In general they seem to have as great a freedom as in some of the occidental countries and through marriage become, in financial matters at least, partners of their husbands.

Being entirely objective though not complete as stated, this book offers data of importance for sociologic analysis and is also very interesting.

There are a glossary of Amharic words and an index.



MATERNAL DEATHS. *A Brief Report of a Study Made in 15 States.* Bureau Publication No. 221.

By U. S. Department of Labor, Children's Bureau. U. S. Government Printing Office, Washington. 5 cents. $9\frac{1}{8} \times 5\frac{7}{8}$; iv + 60; 1933 (paper).

An abstract of a full report of a study made by the U. S. Children's Bureau of all maternal deaths which occurred in thirteen states in 1927 and in these same states and two others in 1928. The report is divided into twelve sections. The first two deal with general considerations and maternal care. The next nine deal with specific causes of death. Each section includes statistical tables and charts and concludes with comment by the Advisory Committee. The final section is devoted to

recommendations by the Advisory Committee, both to the medical profession and to the general public, for action looking to prevention of maternal deaths.



SELECTED REFERENCES IN EDUCATION, 1933. *Supplementary Educational Monographs No. 41.*

By Department of Education, University of Chicago. University of Chicago, Chicago. 90 cents. $9\frac{3}{8} \times 6\frac{1}{2}$; x + 190; 1934 (paper).

After the United States Office of Education was forced to discontinue the *Record of Current Educational Publications* in 1932, the *School Review* and *Elementary School Journal* started a cooperative enterprise to get out monthly lists of selected references in education. This volume is a collection of these monthly lists for the year 1933.

The topics under which the items are grouped and the names of the specialists preparing the lists are presented in the Table of Contents. The items within each list are arranged alphabetically according to authors. This arrangement, it is believed, obviates the need for an index.



TOTARAM. *The Story of a Village Boy in India To-day.*

By Irene Mott Bose. The Macmillan Co., New York. \$1.90. $8\frac{1}{2} \times 5\frac{5}{8}$; xvi + 118; 1933.

Totaram is just a dear, every day little village boy, much like all boys with their favorite haunts, pastimes and love of stories. Through this book we learn much of the folk lore of India. The author is an American who lives in Nagpur, in the Central Provinces of India. In a nearby village she carries on a demonstration garden and chicken run and teaches weaving, and there she has heard many of the tales she relates. Totaram is friendly and any little boy would be pleased to meet him and learn about his country. The book is written for a child by one who understands and loves children.

THE MYSTERY AND LORE OF MONSTERS. *With Accounts of Some Giants, Dwarfs and Prodigies.*

By C. J. S. Thompson. Williams and Norgate, London. 7s. 6d. net. $8\frac{1}{2} \times 5\frac{3}{8}$; 256 + 36 plates; 1934.

A well-written and abundantly illustrated popular treatise for the general reader on biological monsters of all sorts. As D'Arcy Power says in his too-brief foreword this is a book "which would have delighted the hearts of those inveterate sight-seers, Mr. Samuel Pepys and Horace Walpole." The material is treated in two substantially equal parts, the first general and the second devoted to giants, dwarfs and prodigies. There is a substantial bibliography and a detailed index. This book will usefully adorn any library; whether that of a gentleman or that of an undergraduate biological laboratory.



SEMEIOTICA DELLA COSTITUZIONE. *Dottrina e Metodologia Costituzionale Morfologica e Funzionale. Estratto dal Trattato di Semeiotica.*

By G. Viola. Dottor Francesco Vallardi, Milan. $9\frac{1}{2} \times 6\frac{1}{4}$; v + 249; 1933.

This is a valuable addendum to the author's *La Costituzione Individuale* reviewed in this journal (Volume 9, p. 229). Fuller explanation is given for the choice of measurements taken in relation to their anatomic and physiologic significance. The anthropometric technique, recording and elaboration of data are described in every detail. Of special interest are the tables reproducing the somatic data resulting from the observations of the author and of his students on male and female adults and on adolescents of different age groups. The book is well indexed.



SMOKE AND THE ATMOSPHERE. *Studies from a Factory Town.*

By J. R. Ashworth. Manchester University Press, Manchester. 7s. 6d. net. $8\frac{1}{2} \times 5\frac{3}{8}$; xii + 131; 1933.

This book deals primarily with the methodology of studying atmospheric pollu-

tion. The technical details of the construction, calibration and use of apparatus for measuring deposited impurities, particles carried along by the winds, and matter suspended in the air are discussed and the natural and artificial sources of variation are evaluated. Both the experimental work and the statistical analysis of the data collected are carefully done and well presented. There is an index.



TROIS FONDATEURS DE LA MÉDECINE MODERNE: Pasteur, Lister, Koch. Derniers Écrits.

By Élie Metchnikoff. Félix Alcan, Paris. 15 francs. $7\frac{3}{8} \times 4\frac{1}{4}$; xi + 195; 1933 (paper).

This is a collection of three articles written by E. Metchnikoff a few years before his death. The first contains brief biographies of Pasteur, Lister and Koch, in which the author's manifest admiration and devotion add much to an understanding of their individual personalities. Of the other two articles, one is on the necessity of giving children adequate sex education and the last is on the significance of "natural" death, entitled *La mort du Papillon du Murier*. Both are well known and often quoted.



MEDICAL WOMEN OF AMERICA. *A Short History of the Pioneer Medical Women of America and of a Few of Their Colleagues in England.*

By Kate Campbell Hurd-Mead. Froben Press, New York. \$1.00. 9×6 ; 112; 1933.

This is a very brief history of the invasion of the medical field by women. The author seems to feel the need for bolstering up the case for the woman physician and the tone of the book is decidedly one of defense for women in medicine. There is an appendix consisting of an interesting autobiography of Elizabeth Cushman, one of the early women doctors. The volume concludes with several rather nice photographs of the early medical women. There is an index.

THE AMERICAN FAMILY.

By Ernest R. Groves. J. B. Lippincott Co., Philadelphia. \$3.00. 8 x 5½; x + 550; 1934.

The author describes and enumerates the economic, social and physiologic factors which may have produced the changes in the social and personal functions of the American family. It is a good review of the many investigations on the different phases of the problem, but no real attempt is made to measure the degree of influence of the above factors or determine the trend of the changes.



ADDENDA TO A BIBLIOGRAPHY OF THE HONOURABLE ROBERT BOYLE.

By J. F. Fulton. Oxford University Press, New York. (Reprinted from the Oxford Bibliographical Society, Proceedings and Papers, Volume III, Part 3, pp. 339-365.) 10 x 7½; iv + 27; 1933 (paper).

This supplement to Fulton's *Bibliography of Boyle*, reviewed in Vol. 8, pp. 366-7, gives a number of editions and variant issues of Boyle's works not recorded in the original bibliography. An advertisement of the sale of Boyle's library and two poetical references to the bust of Boyle in Queen Caroline's Grotto at Richmond are also included. There is an index.



ÉTUDE ET COMMENTAIRES DU LIVRE CURIEUX D'ATHÉNÉE "Les Deipnosophistes" ou "Banquet des Sages."

By E. A. Herbodeau. Practical Press, London. 3s. 6d. net. 7½ x 4½; 106; no date (paper).

The chef at the Carlton in London writes about the food, drink and table service of the ancient Greeks and Romans, having gleaned his material from Athenaeus' classic *Deipnosophists*.



GUIDING THE ADOLESCENT. U. S. Department of Labor, Children's Bureau Publication No. 225.

By D. A. Thom. U. S. Government Printing Office, Washington. 10 cents. 9½ x 5½; v + 94; 1933 (paper).

LABOR UNDER THE N. R. A.

By Carroll R. Daugherty. Houghton Mifflin Co., Boston. 25 cents per copy (in quantity). 8½ x 5½; 38; 1934 (paper).

CHILD LABOR. Facts and Figures. Bureau Publication No. 197.

By U. S. Department of Labor, Children's Bureau. U. S. Government Printing Office, Washington. 10 cents. 9½ x 5½; vi + 85; 1933 (paper).



ZOOLOGY

PLANT PARASITIC NEMATODES AND THE DISEASES THEY CAUSE.

By T. Goodey. E. P. Dutton and Co., New York. \$6.75. 8½ x 5½; xx + 306; 1933.

This is a very useful account of the life histories, geographical distributions, and host relationships, of a destructive group of plant parasites, and the appearance of this book will be welcomed by everyone who has to deal with these forms. The system of biometric measurements proposed by the late N. A. Cobb is used in the description of the individual species. For each species there is a separate literature review which sets forth the known information concerning its life history and habits, and a list of the plant species it is known to parasitize. The book is characterized by a careful attention to detail throughout; there are numerous illustrations; the name of the authority follows each Latinized plant and nematode name; bibliographies follow each chapter; and there is a good index. In a foreword Professor R. T. Leiper remarks:

As knowledge of the morphology and development of a normal, free-living nematode is obviously a most desirable pre-requisite to an understanding of the parasitic species, one may justifiably stigmatize as a calamity both for the parasitologist and the zoologist the universal use in standard text-books of zoology of the unnaturally large and revolting ascarids of domesticated animals as examples of the Phylum *Nemathelminia*. Indeed the traditional teaching in which the nematodes are utilized chiefly as

illustrations of the phenomena of 'degeneration' and 'parasitism' is probably responsible for the lack of appreciation among zoologists generally of a group which displays a unique and highly efficient organization and in which the free-living representatives outnumber those which have adapted themselves remarkably to new environments.



PAPERS FROM TORTUGAS LABORATORY OF CARNEGIE INSTITUTION OF WASHINGTON. Vol. XXVIII. *Carnegie Institution of Washington Publication No. 435.*

Carnegie Institution of Washington, D. C.
\$1.75 (paper); \$2.25 (cloth). 10 x 6½;
361 + 47 plates; 1934.

The following papers are included in this volume: On the habits and development of certain Atlantic Syngnathi, by C. M. Breder, Jr.; Physiology and morphology of Porifera exemplified by *Iotrochota birotulata* Higgin, by M. W. de Laubenfels; Lime deposition and the bacteria. I. Estimate of bacterial activity at the Florida Keys, by Haldane Gee; Lime deposition and bacteria. II. Characteristics of aerobic bacteria from the Florida Keys, by Haldane Gee and Catharine B. Feltham; Freezing points of bloods of certain littoral and estuarine animals, by A. S. Pearse; Observations on the parasites and commensals found associated with crustaceans and fishes at Dry Tortugas, Florida, by A. S. Pearse; Inhabitants of certain sponges at Dry Tortugas, by A. S. Pearse; Animals in brackish water ponds and pools at Dry Tortugas, by A. S. Pearse; The *Botryllus* type of ascidian larva, by Caswell Grave; Radium radiation effects on regeneration in *Euratella* Chamberlin, by Raymond G. Stone; The genus *Helicometra* and related trematodes from Tortugas, Florida, by H. W. Manter; Variation in size and in nitrogen requirements during early development of the sea-urchin, *Echinometra lucunter*, by Frederick R. Hayes; Growth of some tissues of *Ptychodera bahamensis* in vitro, by L. R. Cary; The selective action of certain adverse environmental conditions of the hermit crab (*Clibanarius tricolor* Gibbes), by B. W. Kunkel; Two new genera and six new species of Amphipoda from Tortugas, by Clarence R. Shoemaker; Some digenetic trematodes from deep-water fishes of Tortugas, Florida, by

H. W. Manter; The mechanism of asymmetry in the Alpheida, by Hugh H. Darby.

While the volume is dated 1934, the greater part of the papers were issued as preprints during 1933.



BUDGERIGARS in Bush and Aviary.

By Neville W. Cayley. *Angus and Robertson, Sydney.* 7s. 6d. 8½ x 5½; xvii + 148; 1933.

An abundance of information on the Australian parrot has been collected and pleasantly presented. Budgerigars, good food to the aborigines, are commonly known as parakeets or love-birds. There are chapters on the history of the species, its habits in bush and aviary, housing, feeding, breeding and management, color production and varieties, its training as a talker and pet, and diseases and their treatment.

The appearance of the color varieties in aviaries during the last one hundred years and the manner in which the practical breeder handles these, without definite knowledge of the genetic factors, combine to make the book interesting. We particularly like this in the chapter on diseases:

Mating Fever. *Symptoms.*—Bird dances and appears highly excited. Spreads out wings and takes a fit somewhat similar to epilepsy.

Cause.—Unsatisfied sexual desire. Chiefly prevalent in unmated males desiring hen.

Treatment.—Same as epilepsy and spray head with cold water. If possible place in company of hen. Failing that, keep him right out of the line of vision of any mated hens.



TERMITES AND TERMITE CONTROL. *A Report to the Termite Investigations Committee.*

Editorial Board: Charles A. Kofoid, *Editor-in-Chief*; S. F. Light; A. C. Horner; Merle Randall; W. B. Herms; Earl E. Bowe. *University of California Press, Berkeley.* \$5.00. 9½ x 6; xxv + 734; 1934.

Thirty-four individuals have collaborated to produce this monograph. The work was sponsored by the Termite Investigations Committee which represented mainly

institutions and industries having extensive interests in California. C. A. Kofoed, Professor of Zoology of the University of California, with five others, representing zoology, civil engineering, chemistry, entomology and forestry, formed the Editorial Board. The study is divided into four parts (with fifty-six chapter headings) as follows: (1) Termites and their biology; (2) Chemical investigations; (3) Termite resistivity of woods and building materials; (4) Prevention and repair of termite damage. The volume is extensively illustrated with photographs and drawings. Statistical data are exhibited in eighty-two tables and a large literature list is given. There is no index but the arrangement of the table of contents offsets to a certain extent the omission. The volume will be highly useful to biologists and teachers as well as to architects, engineers, contractors, building inspectors and users of wood. The proceeds derived from the sale of the book will be devoted to further research on these destructive insects.



BUMBLEBEES AND THEIR WAYS.

By Otto E. Plath. The Macmillan Co., New York. \$4.00. $8\frac{1}{2} \times 5\frac{1}{2}$; xvi + 201; 1934.

The author has been studying and writing about bumblebees for the past twelve years. While he has incorporated in this volume some of his articles which have already appeared in biological journals, these have been thoroughly revised and much condensed. The greater portion of the volume consists of material hitherto unpublished. The life histories and social behavior of thirteen species of true bumblebees (*Bombus*) and four species of parasitic bumblebees (*Psithyrus*) are described in language that the layman can well understand. The author has perfected a technique (described in Chapters X and XI) which will be found highly useful both by the amateur and the more serious student in observing and experimenting with these insects. An appendix gives a detailed account of the more important North American species of bumblebee. The volume is well illustrated, and con-

tains a lengthy bibliography and an index. Professor William Morton Wheeler contributes a foreword.



EXPLORING THE ANIMAL WORLD.

By Charles Elton. George Allen and Unwin, London. 3s. 6d. net. $7\frac{1}{2} \times 4\frac{1}{2}$; 119; 1933.

Mr. Elton always writes interestingly, whether it be for the serious student of science or the amateur. This little book is made up of a series of British broadcast talks given in the spring of 1933, suggesting to the ordinary individual ways in which he can get to know the elaborately organized animal world as it exists in the moors and woods and fields through which he walks. The six chapters treat of how to look for animals; their manner of working and resting; their professions; making a survey of one particular sector of the animal world; animal life at night; sanctuaries for wild life and the part that ecology can play in making them successful; plagues of animals, etc. At the end of the book is given a brief literature list and a brief section on *How to survey woodland birds*. The book is illustrated by several woodcuts by Nora S. Unwin. There is no index.



MAULED BY A TIGER. *Encounters in the Indian Jungles.*

By Arthur W. Strachan. The Moray Press, Edinburgh and London. 12s. 6d. $8\frac{1}{2} \times 5\frac{1}{2}$; xi + 279 + 16 plates; 1933.

Again we are impressed with the heavy moral responsibility there attaches to being an Englishman. This time it is in connection with pursuing and killing wounded animals, even at considerable risk to life and limb. In fact, that is how the author came to be mauled.

It does not make the reading any easier to have a liberal use of native terms which have to be followed by their English equivalents. But even so this is an interesting account of what actually happens where tigers live and steal cattle and have to be killed. There is little of the "sport for sport's sake" attitude; it is mostly

business and rather casual with no elaborate preparations nor hordes of servants. The pictures are delightful. Most of them are reproductions of the author's miniatures on ivory.



MAN-KILLERS I HAVE KNOWN.

By A. J. Siggins. *Wright and Brown, London.* 15 shillings net. $8\frac{7}{8} \times 5\frac{3}{4}$; v + 312; [no date].

Readers of *Shooting with Rifle and Camera* will not find this volume as interesting as the other. The author describes mainly the hunt for lions or leopards that have turned "man-killers." There are very thrilling incidents but every tale is recited in almost identical manner so that towards the end they lose interest. Those relating to crocodiles are better written and more dramatic. Vague allusions are made to human "man-killers" but very little actually reported except for a few incidents of native guerrillas and one or two alleged examples of Portuguese maltreatment of the natives. For the latter the author demonstrates much sympathy and even respect for their superstitions.



THE ELEMENTS OF EXPERIMENTAL EMBRYOLOGY.

By Julian S. Huxley and G. R. De Beer. *The University Press, Cambridge; The Macmillan Co., New York.* \$7.00 (U. S. A.). $8\frac{1}{2} \times 5\frac{1}{2}$; xiii + 514; 1934.

Huxley and de Beer have written an excellent account of experimental embryology, chiefly based on amphibian development in the prefunctional stage, in which emphasis is laid on relative growth as the principle by which determination and differentiation appear in an embryo derived from a non-diversified egg. There is a large amount of data in the literature derived from the experimental analysis of development available for such a treatment and it has been used to good advantage. There is a large number of good illustrations, most of them taken from research journals. The bibliography has

been arranged to serve as an author index and there is a separate subject index.



HANDBOOK OF FROGS AND TOADS. *The Frogs and Toads of the United States and Canada.*

By Anna A. Wright and Albert H. Wright. *The Comstock Publishing Co., Ithaca, N. Y.* \$2.50. $7\frac{3}{4} \times 5\frac{3}{8}$; xi + 231; 1933.

This is an excellent volume for the herpetologist, ecologist, and field-naturalist. It describes clearly and in detail the frogs and toads of the United States and Canada, and gives much general ecological information about their range, habitat, and reproductive habits. The brochure is profusely illustrated with photographs and diagrams and is sensibly bound for a handbook. A good bibliography is appended.



THE CHINESE MEDICAL JOURNAL. Vol. XLVII, Nos. 11 and 12. *Professor Fülleborn Memorial. Parasitology Number.*

Peiping Union Medical College, Peiping. $9\frac{7}{8} \times 6\frac{1}{8}$; 402; 1933 (paper).

A special parasitology number of the *Chinese Medical Journal* prepared as a memorial to Professor Dr. F. Fülleborn, former Director of the Institute of Tropical Diseases at Hamburg. In this issue 362 pages are given to twenty-eight articles which deal with histopathology, morphology of parasites, and various biological relationships of parasites in human diseases. The contributions are all published in English and are well illustrated, and withal give an excellent idea of the status of parasitological studies in China. Some nineteen pages are given to editorials, notes, and news items. The issue also carries the index for the 1933 volume of the *Journal*.



LA MÉTHODE LOEWENSTEIN. *Appliquée au Sang des Bovidés. Acta Veterinaria Neerlandica, Tome I, Fasc. 3.*

By C. F. van Oijen. J. v. Boekhoven, *Utrecht.* $9\frac{1}{2} \times 6\frac{1}{2}$; 64; 1934 (paper).

A report of the work of the author and his collaborators in the Faculty of Veterinary Medicine at the University of Utrecht on tuberculous bacillema in animals, following the Loewenstein technique. The results showed that tubercle bacilli were detected:

- in the venous blood, leaving a tuberculous organ (e.g. the udder of the cow),
- in the blood extracted from the Vena jugularis in animals after experimental infection,
- in the blood extracted from the heart of those animals and in one case of spontaneous tuberculosis,
- in the meat juice from several animals.



THE CULT OF THE GOLDFISH.

By T. C. Roughley. Angus and Robertson, Sydney. 6 shillings. 8 $\frac{1}{2}$ x 5 $\frac{1}{2}$; xiii + 146; 1933.

This is a book destined for a warm reception by naturalists and the fish-fancier clan. It gives information, calmly and interestingly, about the numerous varieties of goldfish and presents well the rather surprising amount of technical knowledge required for their optimal care. Certain illustrations add to the value of the book.



LA VIE DE LA MANTE RELIGIEUSE.

By Léon Binet. Vigor Frères, Paris. 20 francs (paper); 40 francs (de luxe edition). 9 $\frac{1}{2}$ x 7 $\frac{1}{2}$; 92; 1931.

A brief, but good, account of the life history of the fascinating Praying Mantis (*Mantis religiosa*). It is provided with illustrations and a bibliography of six pages. We were sorry to note several typographical errors, especially the one in line 1 of the text where the Christian name of the insect is given as *reliogisa*.



A MALARIA-LIKE DISEASE OF DUCKS Caused by *Leucocytozoon anatis* Wickware. University of Michigan, School of Forestry and Conservation Bulletin No. 4.

By Earl C. O'Roke. University of Michigan Press, Ann Arbor. 25 cents. 9 x 6; 44 + 5 plates; 1934 (paper).

A report on three years of study of a disease that attacks both tame and wild ducks. The stages in the life history of the protozoan parasite, *Leucocytozoon anatis* Wickware, are described in detail; supplemented by plates made from cytological preparations of the organism. The disseminating host is the common black fly, *Simulium venustum*. Practical methods of control are outlined.



LES PAGURES OU BERNARDS L'ERMITE. (Un Exemple d'Adaptation). Actualités Scientifiques et Industrielles 101. Exposé de Biologie Zoologique.

By Charles Pérez. Hermann et Cie, Paris. 9 francs. 10 x 6 $\frac{1}{2}$; 33; 1934 (paper).

A highly interesting account of the hermit crab and the changes of its anatomical structure for adapting it to making use of shells and sponges as habitat and protection. The illustrations are excellent.



STREIFZÜGE DURCH DIE UMWELTEN VON TIEREN UND MENSCHEN. Ein Bilderbuch unsichtbarer Welten.

By J. Baron Uexküll and G. Kriszat. Julius Springer, Berlin. 4.80 marks. 7 $\frac{1}{2}$ x 4 $\frac{5}{8}$; x + 102; 1934.

Curious and interesting pictures and descriptions of the environment of animals.



THE MORPHOLOGY OF HAPTOPHYA MICHIGANENSIS WOODHEAD, AN ASTOMATOUS CILIATE FROM THE INTESTINAL TRACT OF HEMIDACTYLUM SCUTATUM (SCHLEGEL). University of California Publications in Zoology, Vol. 39, No. 12.

By Mildred Bush. University of California Press, Berkeley. 10 $\frac{1}{2}$ x 6 $\frac{3}{4}$; 26 + 3 plates; 1934 (paper).

A NEW RACE OF CHIPMUNK FROM THE GREAT BASIN OF WESTERN UNITED STATES. University of California Publications in Zoology, Vol. 40, No. 6.

By E. Raymond Hall and Donald M. Hatfield. University of California Press, Berkeley. 10 $\frac{1}{2}$ x 6 $\frac{3}{4}$; 5; 1934 (paper).

PUBLICATIONS OF THE UNIVERSITY OF OKLAHOMA BIOLOGICAL SURVEY. *Volume V.*
 No. 1. *Howard Atwood Kelly*, by A. I. Ortenburger and Roberta D. Ortenburger. No. 2. *The Decapod Crustaceans of Oklahoma*, by E. P. Creaser and A. I. Ortenburger. No. 3. *The Ecology of the Western Oklahoma Salt Plains*, by A. I. Ortenburger and R. D. Bird. No. 4. *Notes on the Occurrence of Mammals in the Regions Adjacent to the Salt Plains of Northwestern Oklahoma*, by H. H. T. Jackson and H. E. Warfel.

University of Oklahoma Press, Norman.
 \$1.00. 9 x 6; 87; 1933 (paper).



BOTANY

PLANTS AND HUMAN ECONOMICS.

By Ronald Good. *The University Press, Cambridge; The Macmillan Co., New York.*
 \$1.75. 7½ x 4½; xii + 202 + 8 maps; 1933.

A new approach to the study of botany. The author aims to make the science of plants something more than a means of mental discipline. Botanical facts form the basis of the text but the emphasis is put on the implications of the science from a humanistic and economic point of view. In order that the reader may more readily grasp the general aspects of the book it seems best to list the chapter headings. An introductory chapter deals with foodstuffs and raw industrial materials, then follow sections on: The nature and sources of food; The life of the green plant; Factors limiting agricultural production; Science and agriculture; Cereals and pulses; Vegetables: salad plants: fruits; Beverages: sugar and starch: oils and fats: spices; Timber, coal and petroleum; Rubber: resins, balsams and gums: tans and dyes: fibres; Alcohol: drugs: fodders: miscellaneous; The useful products of the lower plants: Concluding notes on vegetable products; The economic botany of Great Britain. A series of maps show the distribution of foodstuffs and plant products. There is also included an appendix giving scientific and English names of common plants, a selected reference list and an index.

AMERICAN TOBACCO TYPES, USES AND MARKETS.

By Charles E. Gage. *U. S. Government Printing Office, Washington.* 20 cents. 9½ x 5½; 88 + folding map; 1933 (paper). This pamphlet deals with one of the most interesting of the industries concerned with agricultural products. It is interesting not only because of the stringent climatic and edaphic limitations that confront the tobacco grower but because of the peculiar preferences of the buying public, and the users of tobacco are scattered over enough continents to have developed some curious tastes. The treatment is that of the agricultural economist, primarily; there are numerous detailed statistical tables of crop production in the various tobacco producing regions of this country, together with notes on the amount of caution necessary in interpreting them, and brief descriptions of the cultural practices prevailing in different sections. Most interesting of the statistical data, perhaps, are a table showing the annual consumption of tobacco products in this country since 1880 and a large map of the tobacco growing regions. There is a large amount of interesting information about the human foibles that have to be catered to, and, in some cases, explanations as to how apparently arbitrary preferences of long standing have arisen.



A SHORT HISTORY OF GARDENS.

By H. N. Wethered. *Methuen and Co., London.* 12s. 6d. net. 7½ x 5½; xv + 323; 1933.

Mr. Wethered has, one might say, done the history of gardens up good and brown. One is interested to learn how the geographical, climatic, and national temperament of a land and its people affect its gardens. The story begins in Egypt, and is traced through Homer, the two Plinys, the fantastic gardens of Byzantium and Baghdad, where trees of gold bore fruits of precious gems, the monastery gardens of the Middle Ages, and the Renaissance gardens of Italy to Versailles and Hampton Court, and thence through Capability Brown to the modern garden, where our love of athletics is reflected in the inclu-

sion of the tennis court and swimming pool. The author has given us a very readable history which will interest the student of the origin of ideas as well as the lover of gardens. There is an index.



BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY. *A Key for the Identification of Organisms of the Class Schizomycetes. Fourth Edition.*

By David H. Bergey. Assisted by a Committee of the Society of American Bacteriologists: Robert S. Breed, Frank M. Huntoon, Bernard W. Hammer, E. G. D. Murray, Francis G. Harrison. With an Index by Robert S. Breed. The Williams & Wilkins Co., Baltimore. \$6.00. 9 x 6; xvi + 664; 1934.

Each new edition of this widely used manual is larger than its predecessor by about 100 pages. In this fourth edition

Two new genera have been recognized in Tribe *Bacteriaceae*, namely Genus *Brucella* and Genus *Listrella*. Genus *Pfeifferella* has been combined with Genus *Actinobacillus*.

Information was available for the amplification of the descriptions of species of the following genera: *Leuconostoc*, *Propionibacterium*, *Bacterioides*, and Order *Mycobacteriales*.

Descriptions of about 50 new species have been included while several organisms have been omitted as distinct species and the names recognized as synonyms for other species.



POST-LOGGING DECADENCE IN NORTHERN HARDWOODS. *University of Michigan, School of Forestry and Conservation Bulletin No. 3.*

By Ralph C. Hall. *University of Michigan Press, Ann Arbor.* 25 cents. 9 x 6; 66; 1933 (paper).

A study contributing to better management of our northern hardwood forests. The author shows that the bronze birch borer is not a primary pest of the forest birch, and that post-logging decadence is conditioned by many physical, physiographic and biotic factors. The intensity of any cutting must be conditioned by the general character of the forest and not by mere size utility of the trees if injury is to be avoided. The ecological data are

treated statistically, and in a brief appendix the constants used are defined, following the methods popularized by Harris.



ÉTUDE ÉCOLOGIQUE ET PHYTOSOCIOLOGIQUE DE L'ASSOCIATION À BRACHYPODIUM RAMOSUM ET PHLOMIS LYCHNITIS DES GARIGUES LANGUEDOCIENNES. *Communication No. 18.*

By F. R. Bharucha. *Station Internationale de Géobotanique Méditerranéenne et Alpine, Montpellier.* 9½ x 6½; 132; 1931 (paper).

A careful and intensive ecological survey of the garigue in the vicinity of Montpellier was made under the direction of Professor Braun-Blanquet, and the results presented here are reprinted from the *Beibeste zum botanischen Centralblatt*, 50: 247-379, 1933. This association appears to be one of the last stages of degeneration of oak forest under the influence of cutting and burning. The soil, of course, has been greatly influenced by these disturbances, and careful attention was paid to its characteristics. Almost every method now in use by plant ecologists was employed and the whole investigation is characterized by thoroughness and completeness.



CULINARY HERBS AND CONDIMENTS.

By M. Grieve. *Harcourt, Brace and Co., New York.* \$2.00. 7½ x 5; v + 209; 1934.

A book highly useful to all those interested in the art of cookery. It contains a complete catalogue of all the culinary herbs with descriptions and details concerning their cultivation. Many recipes are given to illustrate the uses of the herbs. There is a special section giving recipes for home-made wines, herbal beers and other herbal beverages, a section on condiments and culinary oils and one on cooking utensils. The volume is indexed.



GARDEN FLOWERS IN COLOR. *A Picture Cyclopaedia of Flowers.*

By G. A. Stevens. The Macmillan Co., New York. \$3.75. 9 x 6; 320; 1934. This is an attractive assemblage of colored illustrations of garden flowers and ornamentals. The pictures of each type are accompanied by a brief note on habits of growth and flowering, and there are many suggestions on the best use in planting. It should be most useful in planning seasonal color combinations for the garden. Reference is facilitated by an index that gives both botanical and vernacular names.



RECENT ADVANCES IN PLANT PHYSIOLOGY. Second Edition.

By E. C. Barton-Wright. P. Blakiston's Son and Co., Philadelphia. \$4.00 net. 7 $\frac{1}{8}$ x 5 $\frac{1}{2}$; x + 341; 1933.

This is the second edition of a textbook for advanced students of plant physiology dealing with recent advances in fields in which research is most active at present. Only minor changes appear to have been made during revision and most of the literature references are to articles in English. There is an excellent index.



SILVA FENNICA 27. *Der Holz-mangel in Finnland von 1809, seine Gründe und die Massregeln zu seiner Bekämpfung.*

By Martti Hertz. Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 66; 1933 (paper).

SILVA FENNICA 28. *The Pulpwood Question.* Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 142; 1933 (paper).

SILVA FENNICA 29. *Über tägliche Herstellungsmengen von Papierholz in Perä-Pohjola in den verschiedenen Jahreszeiten.*

By Einar Maliniemi. Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 14; 1933 (paper).

SILVA FENNICA 30. *Die waldbauwirtschaftliche Kontrolle der Waldwirtschaft.*

By V. Lihtonen. Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 52; 1933 (paper).

SILVA FENNICA 31. *The Small Timber Problem.*

Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 219; 1933 (paper).

SILVA FENNICA 32. *Über die Vegetation des Naturparks von Hiisjavi.*

By Alfred Brandt. Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 1933 (paper).

SILVA FENNICA 33. *Über die besondere Stellung des Waldarbeiters im Arbeitsrecht.*

By Mauno Forsström. Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{5}{8}$ x 6 $\frac{3}{8}$; 30; 1933 (paper).

ACTA FORESTALIA FENNICA 39.

Publications of the Society of Forestry in Suomi (Finland), Helsinki. 9 $\frac{1}{2}$ x 6 $\frac{3}{8}$; 1933.



MORPHOLOGY

THE CORTICAL LOCALISATION OF CEREBRAL FUNCTION.

By J. Shaw Bolton. Oliver and Boyd, Edinburgh. 6 shillings. 9 $\frac{3}{4}$ x 7 $\frac{3}{8}$; 23 + 12 plates; 1933 (paper).

In 1832 Mr. William Ramsay Henderson died in Edinburgh leaving a trust fund for "the advancement and diffusion of the Science of Phrenology." Although Phrenology as Mr. Henderson probably understood the term is long since dead the problem of the relation between cerebral structure and function is still very much alive. In this lecture under the Henderson Trust Professor Bolton deals with this relation in the neopallium, which "provides for the individual motor educability which is the peculiar and paramount characteristic of the mammalia compared with the lower forms of animal life." He traces briefly its phylogenetic and ontogenetic development and correlates the gross and microscopic structural defects with clinical symptoms.

The prefrontal cortex is late in evolution, high in complexity, and low in stability. The mental disease so common in man is the natural consequence of the over-stepping of the limits of capability and of durability, and must be regarded as the penalty still paid by man for the gift of volition, and as evidence of the relatively recent evolution, in geological time, of this capability.

THE ANATOMY OF THE RHESUS MONKEY (*Macaca mulatta*).

By T. H. Bast, Kermit Christensen, Harold Cummins, Frederick D. Geist, Carl G. Hartman, Marion Hines, A. Brazier Howell, Ernst Huber, Albert Kuntz, S. L. Leonard, P. Lineback, John A. Marshall, Gerrit S. Miller, Jr., Rush A. Miller, Adolph H. Schultz, T. D. Stewart, William J. Straus, Jr., W. E. Sullivan, Geo. B. Wislocki. Illustrated by Benjamin Kopel. Edited by Carl G. Hartman and William L. Straus, Jr. *The Williams and Wilkins Co., Baltimore.* \$6.00. 9 x 6; ix + 383; 1933.

Representing largely the individual researches of nineteen collaborators, this work furnishes a greatly needed systematic handbook of the anatomy of one of the most important laboratory animals. A chapter is devoted to each anatomical system and the senior editor contributes a very valuable appendix on the housing and care of monkeys. Without exception each section is carefully and concisely written; the illustrations by Benjamin Kopel are simply and clearly executed; and a complete index rounds out the volume. It is certain that the editors' hope "... that the book attains the immediate object of affording a useful description of the rhesus monkey for research workers ..." will be realized.



INTRODUCTION TO CYTOLOGY. *Third Edition.*

By Lester W. Sharp. *McGraw-Hill Book Co., New York.* \$5.00. 9 x 5½; xiv + 567; 1934.

This edition has been altered to improve "its adaptability to the needs of students with comparatively little experience in the special field of cytology, without, however, making it an elementary treatise. To this end much of the material has been rearranged; the treatment of many points has been simplified, and certain borderline topics have been omitted altogether." Most of the citations to literature have been transferred to footnotes. The bibliography has been completely revised and forty new illustrations added.

HUMAN EMBRYOLOGY AND MORPHOLOGY. *Fifth Edition.*

By Sir Arthur Keith. *William Wood and Co., Baltimore.* \$10.00. 9 x 5½; viii + 558; 1933.

The last edition of this well-known textbook appeared in 1923. The present edition has been completely revised and reset. Two new chapters—IV on physiological and pathological embryology, and XXI on organs of digestion (continued)—have been added, while much new material on experimental embryology has been included in the various chapters. References to recent publications have been collected at the end of each chapter instead of in footnotes as in previous editions.



THE STUDY OF ANATOMY. *Written for the Medical Student. Second Edition, Rewritten and Enlarged.*

By S. E. Whitnall. *William Wood and Co., Baltimore.* \$1.50. 7½ x 4½; v + 93; 1933.

Good advice to medical students about many things—necessity of clean hands as well as how to study anatomy. Committed to the thesis that "form is determined by function" the book outlines the way anatomy should be learned. It is not in any sense an anatomy laboratory guide, but it is full of sensible advice and is very interesting reading. There is a bibliography of 122 titles.



PHYSIOLOGY AND PATHOLOGY

RÔLE DU SYSTÈME NERVEUX ET DES FACTEURS BIOLOGIQUES ET PSYCHIQUES DANS L'IMMUNITÉ.

By S. Métalnikov. *Masson et Cie, Paris.* 28 francs. 9½ x 6½; 166; 1934 (paper).

The author summarizes the results of his experiments showing the importance of the nervous system in immunity. The most interesting of these was that of conditioning guinea pigs and rabbits so that without antigen injection but only by auditory or tactile stimulation the usual leukocyte reaction was obtained and for

the expected length of time. He reports not only leukocytosis but, for the guinea pig at least, the usual formula of increase in polynuclears, followed by that of mononuclears. These observations, which may be justly doubted, have not been always confirmed by other workers. The failures are attributed by the author to lack of precautions in the conditioning of the animals. He offers as critical proof a series of experiments in which, accompanied by an external stimulus, he inoculated guinea pigs with an emulsion of heated staphylococci twenty times. Twenty days following the last injection some of the animals were given the external stimulation and immediately afterwards all were injected with a mortal dose of *B. cholerae*. Those that had not received the external stimulus died within twenty-four hours, the others are still alive! [Reginald the Office Boy wants to know whether the tune played was "Smoke Gets in Your Eyes" or the "Marseillaise." He says it might make a difference.]

Such astounding results deserve further experimentation by less sanguine observers. Apparently, from the author's description, the experiments were as well conducted and controlled as in most laboratories.

There is a bibliography of 121 titles.



THE BRAIN AND ITS MECHANISM.

By Sir Charles Sherrington. *The Macmillan Co., New York; The University Press, Cambridge.* 50 cents (U. S. A.). $7\frac{3}{8} \times 5$; 35; 1933 (paper).

In this Rede lecture the distinguished neurologist gives a brief account of the mechanism of the nervous system and a discussion of the mind-body problem. He concludes that

we have to regard the relation of mind to brain as still not merely unsolved but still devoid of a basis for its very beginning. I am not a defeatist, for I would urge active pursuit of the enquiry. Even on the old line of deciphering principles of action of the brain in its management of muscle in the hope of clues to its ways of working in regard to mind. Not that any reflex principle seems applicable to mental activity. The reflex implies an end-result at which the nerve-process having shot its bolt stops and goes no further. But attempted correlation

of mind with brain activity indicates for the latter through-line processes which are in no sense end-effects at all. Nevertheless, there are broad analogies. May we not think that anyhow there is no transmission from a, so to say, mental power-head, but a subtle spread of action over an unstable train, its strength at any point resting on the stability at that point? A ghost may be a very weak visual stimulus and yet release a large mental reaction.



SOME FACTORS IN THE LOCALISATION OF DISEASE IN THE BODY.

By Harold Burrows. *William Wood and Co., Baltimore.* \$5.25. $8\frac{1}{2} \times 5\frac{1}{4}$; xi + 299; 1932.

Professor Burrows here attempts to bring together a large amount of scattered information on the physiology of the localisation of disease processes. The three parts of the book deal respectively with: (a) localisation of colloidal matter, bacteria, and cells from the blood stream; (b) changes in the permeability of the capillary endothelium, transport of matter from the blood stream to the tissues, and the retention of matter by inflamed tissue; and (c) a general discussion of the inflammatory barrier and endothelial permeability. Three significant conclusions are drawn concerning the conditions which are required for localisation of many blood borne diseases:

1. An abnormal permeability of the walls of the small blood vessels.
2. The presence of forces which will transport the noxious agents through the endothelial cytoplasm.
3. The retention of noxious agents in the tissues under the influence of inflammation.

The value of the book is enhanced by a bibliography of over 400 references, and an index.



CARACTERISTICAS REGIONALES DE LA PATOLOGIA DIGESTIVA DE ANDALUCIA OCCIDENTAL Y EXTREMADURA.

By José M.º González Galvan. Dr. José M.º González Galvan, *Albareda, 30, Sevilla, Spain.* $9\frac{1}{8} \times 6\frac{1}{8}$; 44; 1933 (paper). This is a study of the sex, dietary habits,

general constitution and mode of living of 3754 patients suffering from gastro-intestinal diseases. From these observations the author attempts to construct "personalities" which he considers associated with the different diseases and in a way characteristic of Western Andalusia and Estremadura. He describes: the "ulcer personality," usually found in males, hard working and of careless dietary habits; the "gastric," more frequent in males who are great imbibers of wine; the "neurotic" found generally in neurotic females; the "ptotic," more common in women of flaccid physique, either virgin or too fertile multiparous; etc. It is not evident that these "personalities" are exclusively characteristic of that region.

The statistical data of disease incidence, though interesting, cannot be used for comparison because incomplete. Noticeable is the small percentage of malignancies (diagnosed in about 3 per cent of the patients), but since the age distribution is not given the significance cannot be judged.



PHYSIOLOGY OF MUSCULAR ACTIVITY.

By Edward C. Schneider. W. B. Saunders Co., Philadelphia. \$2.75 net. 7½ x 5½; 401; 1933.

Within recent years there has been an increasing number of physiological studies on the effects of exercise, some of them being comparisons of athletes and non-athletes or observations on a group of men during a period of training, while other investigations have been made on athletes participating in the Olympic games and other major sporting events, particularly the more gruelling events like Marathon runs and rowing races. It is interesting to note that a trained man can perform a given amount of work with a smaller consumption of oxygen and with a greater mechanical efficiency than an untrained man, quite apart from the superiority in coördination to be expected from the athlete. Many of these studies have been sound contributions to physiology and they have served to supplement laboratory experiments in a very useful way. This book not only presents the results of

work of this kind in a very nice way, but it also supplies the background in physiology necessary for an appreciation of the experiments, and it should present no great difficulties for anyone with a college course in physiology.

There is a good index and an extensive bibliography.



L'ÉVOLUTION DE LA LUTTE CONTRE LA SYPHILIS. *Un Bilan de 25 Ans.* Nancy 1907-1932.

By Louis Spillmann. Masson et Cie, Paris. 30 francs. 9 x 5½; vii + 292; 1933 (paper).

Combining true missionary zeal with a sound realistic attitude, Dr. Spillmann has for twenty-five years led a campaign to check the propagation of syphilis in the Moselle district of France. In this volume he presents his methods and objectives. The means he has used differ from those generally adopted by the health boards in our more progressive cities in two particulars worthy of mention. One is the extensive use of propaganda—personal appearances, radio talks, pamphlets, books, etc., to inform the youths, of the working class especially, of the signs, symptoms and mode of progression of syphilis, emphasizing the necessity and benefits of early treatment. The other remarkable feature of his organization is the success in tracing and eliminating sources of infection. Like most physicians he realizes the futility of attacking prostitution and therefore limits himself to attempts to maintain it under strict medical control.

This book should be of encouragement to the syphilologists and others who are seeking a solution of this important problem in public health.



CLINICAL STUDIES ON THE PHYSIOLOGY OF THE EYE.

By J. Grandson Byrne. H. K. Lewis and Co., London. 10s. 6d. net. 8½ x 5½; x + 144; 1934.

This volume of some 140 pages is designed to aid clinicians in the practical applica-

tion of the author's experimental work published under the title *Studies on the Physiology of the Eye*. The conclusions from the earlier publication are reiterated. Considerable space is given to diagnostic case histories supplemented by careful descriptions of the eye reactions, photographic reproductions and diagrams. The author shows how the "pseudo-paradoxical" phenomenon may be useful in distinguishing between malingerers and true sufferers from injury. And he also develops the thesis that study of the pupillary responses should be made an integral part of all routine physical examination. Although the book may not appeal as a facile manual, it is full of important clinical, experimental, and practical knowledge directly applicable in diagnostic technique. There are bibliographies at the end of several chapters, and an index.



VETERINARY HYGIENE. Second Edition.

By R. G. Linton. W. Green and Son, London. 21 shillings. 9 $\frac{3}{8}$ x 6; xix + 472; 1934.

This book first appeared in 1921. It was written for the veterinary student, the practitioner and others concerned with the well-being of animals. The second edition has been thoroughly revised and extended. The section on Sanitary Law, appearing in the first edition, has been omitted; also the greater part of the section dealing with preventable diseases, only an account of those notifiable in Great Britain being retained. A section on the housing of poultry and an account of the more common diseases has been added, also sections on dips and dipping and on construction of dog kennels. That part treating of the processes involved in sewage purification has been extended. The volume contains numerous diagrams and photographs, statistical data and occasional references to literature. It is indexed.



A SHORT HISTORY OF THE EPIDEMIC INFECTIOUS DISEASES.

By E. W. Goodall. John Bale, Sons and

Danielsson, London. 3s. 6d. net. 7 $\frac{1}{8}$ x 4 $\frac{3}{4}$; 113; 1934.

A short history of one of the more specialized fields of science might be presumed to be either a carefully selected group of dramatic incidents in the development of the discipline or a compact compendium of dates, names and facts. Good books of the former kind, like Sir Michael Foster's *The History of Physiology*, are rare and it is the privilege of few to write them. Quite certainly Doctor Goodall has not succeeded. Beginning with a short chapter on the nature of infection and a brief review of the notable epidemics, the author summarizes rapidly pertinent facts in the history of plague, small-pox, chicken-pox, measles, and so on, and closes with a short note on epidemiology and prevention. The book is carefully and painstakingly, but not very interestingly, written.



COLD SPRING HARBOR SYMPOSIA ON QUANTITATIVE BIOLOGY. Volume I.

The Biological Laboratory, Cold Spring Harbor, Long Island, N. Y. \$2.90. 10 $\frac{1}{4}$ x 7 $\frac{1}{2}$; xi + 239; 1933.

The twenty-eight short papers in this volume were read by invitation at the Cold Spring Harbor Symposium on Quantitative Biology in July 1933, and are characterized by their mathematical approach to the biological problems concerned. For the most part the subjects discussed can be grouped under the headings of biocolloids, electrophysiology, and oxidation-reduction phenomena in living systems, and they are presented in the form of lectures to advanced students of the subject. The papers are followed by short bibliographies and by digests of the discussion which followed their reading. This is intended to be the first of a series of annual symposia.



VERSUCHE EINER DEUTUNG DER PATHOGENESE DER SKELETTVERÄNDERUNGEN BEI CHONDRODYSTROPHIA FOETALIS (KAUFMANN). *Acta Pathologica et Microbiologica Scandinavica, Supplementum 15.*

By Åke Wilton. *Levin and Munksgaard, Copenhagen*. Dan. Cr. 10. 10 x 6½; 168; 1933 (paper).

The author of this excellent study of *Chondrodystrophia foetalis* concludes that the etiology of this disease is the same as that of rickets, except that it attacks the individual in intra-uterine, rather than extra-uterine, life. The same biological disturbances—deficiency of vitamins, hormones or organic salts, or lack of balance among them—are involved in both diseases. The author suggests that the name *Chondrodystrophia foetalis* be replaced by the older and more correct designation *Rachitis foetalis*. A five-page bibliography is appended.



A SHORT HISTORY OF PHYSIOLOGY.

By K. J. Franklin. *John Bale, Sons and Danielsson, London*. 3s. 6d. net. 7½ x 4½; vii + 122; 1933.

This is one of a series of histories of the medical sciences under the editorship of Arnold and Maurice Sorsby. After an account of the Greek physiologists, chapters are devoted to Leonardo da Vinci and Vesalius. The work in the sixteenth century on the pulmonary vascular system and the valves of veins is then traced, leading up to Harvey's demonstration of the circulation of the blood. With the quickened pace of physiological research in the centuries since Harvey, it is inevitable that a short history should record the work of this period in less detail. In his preface the author acknowledges his chief sources. There is an index of names.



CONTAGIOUS DISEASES. *What They Are and How to Deal With Them*.

By W. W. Bauer. *Alfred A. Knopf, New York*. \$2.00 net. 7½ x 5; xiv + 218; 1934.

Grandmother's "doctor book" gone modern! And really modern and up-to-date. The author furnishes the mother of a family with good, sound, yet simple advice about some of the things a public

health department should do and what she should do about contagious diseases. The section on immunity is very good. There are separate chapters on the different diseases as well as practical suggestions on the care of the sick. There is a glossary of terms and an index.



HYDROLOGIE EXPÉRIMENTALE.

By Maurice Villaret and L. Justin-Besançon. *Masson et Cie, Paris*. 50 francs. 9½ x 6½; 271; 1933 (paper).

A study of mineral waters from European spas as they affect the contraction of isolated smooth muscle fibers. There are some 120 kymographic tracings which clearly show change in tonus, rhythm, and other effects such as antagonisms to stimulating chemicals. The author reports constant reactions for a given water with a fixed technique. However, he reserves any broad clinical or biological conclusions, and offers his data as descriptive material in characterization of the waters.



OUR MYSTERIOUS LIFE GLANDS and How They Affect Us. *A Popular Treatise on Our Glands and Their Secretions—What They Do to Us, How They Affect Our Health, Growth, Appearance, Temper, Mentality, and Character, Including The Vitamins*.

By William J. Robinson. *Eugenics Publishing Co., New York*. \$2.50. 8½ x 5½; xx + 291; 1934.

A volume by a prolific writer presenting general knowledge about the relation of our endocrines to our well-being. The book has the attribute of text organization and to some readers it will be interesting—possibly even exciting. Biologists (not mediceos) may take exception to the following statement:

.... With all due respect to our relations—mice, rats, rabbits, guinea pigs, capons, and tadpoles—sexuality is so different in man than it is in other species, that great as are the similarities, the differences are still greater.

LA SYPHILIS EXPÉRIMENTALE. *Étude Critique et Nouvelles Recherches.*

By P. Gastinel and R. Pulvenis. Masson et Cie, Paris. 45 francs. 10 x 6½; 244; 1934 (paper).

A comprehensive study on experimental syphilis with particular reference to the authors' own work on rabbits. Of major interest to the biologist and clinician appear the observations on the several types of lesions, the different organic reactions to infection, the various factors which modify the evolution of the disease, the nature and mechanism of immunity and its relation to allergic phenomena. The authors attach great importance to the Meinicke test and offer considerable evidence to prove its sensitivity and validity.



THE MODIFICATION OF VESTIBULAR NYSTAGMUS BY MEANS OF REPEATED ELICITATION. *Comparative Psychology Monographs*, Vol. 9, No. 5, Serial No. 45.

By O. H. Mowrer. The Johns Hopkins Press, Baltimore. 75 cents. 10 x 6½; 48; 1934 (paper).

Reduction of post-rotation nystagmus takes place when pigeons are subjected to repeated rotations for a certain length of time and in given conditions. The merit of this report consists in showing that this phenomenon is markedly evident when the animals are subjected to bodily rotations with vision excluded. The mechanism underlying this "habituation" is unknown, but there are various theories which the author reviews. The experiments have been well conducted, though on relatively few animals. There is a bibliography of 65 titles.



TRAITÉ DE PHYSIOLOGIE NORMALE ET PATHOLOGIQUE. Tome V: *Respiration.*

By Léon Binet, L. Dautrebande, H. Hermann, C. Heymans, Pierre Thomas. Published under the direction of G.-H. Roger and Léon Binet. Masson et Cie, Paris.

80 francs (paper); 100 francs (cloth). 9½ x 6½; xvi + 474; 1934.

In this volume of the comprehensive eleven-volume French text book of physiology L. Binet contributes chapters on the histophysiology and biochemistry of the lung, the internal functions of the lung, and physio-pathological studies of various respiratory disturbances; P. Thomas contributes a biochemical study of respiration; L. Dautrebande writes of the gaseous exchanges; and H. Hermann of basal metabolism. The high standard set in earlier volumes is well maintained.



PHYSIOPATHOLOGIE DES SYNDROMES ENDOCRINIENS.

By Noël Fiessinger. Masson et Cie, Paris. 40 francs. 9½ x 6½; 317; 1933 (paper).

A concise but thorough review of the most important studies on the physiology and pathology of the endocrine glands and of the other organs which also secrete internally. The authority of the writer, combined with the clarity of style, makes this an excellent textbook. The various experimental procedures from which the fundamental physiologic facts have been derived are described in detail. There is no index.



L'EXCITATION ÉLECTRIQUE DES TISSUS. *Essai d'Interprétation Physique.*

By A.-M. Monnier. Hermann et Cie, Paris. 85 francs. 10 x 6½; xvi + 326; 1934 (paper).

This highly technical study on the electric stimulation of tissues is based on the work and hypotheses of Lapicque. The author attempts to give a purely physical interpretation of these phenomena and arrives at a general equation that expresses the different physiologic manifestations as deriving from one electrophysical system. Lastly he dwells at length on the significance of chronaxie and on its importance as unit of measure of electric excitation. There is a bibliography of 297 titles.

POLARISATION ET DÉPOLARISATION CELLULAIRES. *Actualités Scientifiques et Industrielles* 100. *Exposés de Biologie Générale en rapport avec la Cytologie.*

By M. Dubuisson. Hermann et Cie, Paris. 12 francs. 10 x 6½; 47; 1934 (paper).

The hypotheses advanced to account for membrane potentials in living cells are discussed and the recent experimental work on the subject is briefly reviewed. The presentation is clear and concise and this booklet ought to be very useful to anyone beginning the study of this subject. There is a bibliography of 84 titles, most of them in English or German.



KREBS im Lichte biologischer und vergleichend anatomischer Forschung. I. Band: *Krebs im Ectodermgebiet.*

By Josef Lartschneider. Franz Deuticke, Leipzig and Vienna. 10 marks. 7½ x 5½; 192; 1934 (paper).

A study of the biology and comparative anatomy of cancer of the ectoderm. The author covers the research and the theories advanced in Germany and Austria thoroughly. There is a bibliography confined mostly to German titles, and an adequate index.



HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. Lieferung 424. *Methoden der Muskel- und Nervenphysiologie. Die Methode der Licht-Stromformung.*

By Ludwig Nicolai. Urban und Schwarzenberg, Berlin. 5 marks. 10 x 7; 89; 1934 (paper).

Lieferung 424 discusses the operation of photo-electric cells, both of the vacuum and of the selenium type, and describes vacuum tube amplifying equipment to actuate registering devices.



BIOCHEMISTRY

THE LYOPHILIC COLLOIDS (*Their Theory and Practice*).

By Martin H. Fischer and Marian O. Hooker. Charles C. Thomas, Springfield, Ill. \$4.50. 9½ x 6½; viii + 246; 1933.

Fischer and Hooker have collected the results of a long series of observations on the stability and the electrical conductivity of the colloidal mixtures of phenol and of soap with water in this book. Regarding these systems as models of living matter, and reasoning by analogy:

The evidence presented, compels the conclusion that neither living matter nor any fraction of it is to be thought of primarily as a dilute solution or as anything approximating such a system. It is, rather, a protein to which the salts have been bound chemically (fundamentally as a base-protein-acid compound) and in which water has then been "dissolved" (or to which the water has been bound as a hydrate). This four part affair is to our minds the fundamental unit of the living mass. . . .

If the conclusion is accepted that all the water of the living mass is held in bound form it leads to an important corollary. The chemical reactions which occur in living matter must occur in a medium far different from ordinary water. *Living matter is normally a practically anhydrous medium; the chemical reactions characteristic of the normal life of the cell occur in an anhydrous medium and their course and products must, in consequence, be entirely different from the course and products of these same reactions occurring in and familiar to us from study of the ordinary aqueous solution.* (Italicized by the author.)

Fischer disagrees with a large number of physiologists on many other points, notably on the existence of semi-permeable membranes and on the rôle of osmotic pressure. The book is provided with an index.



AN INTRODUCTION TO BIOCHEMISTRY.

By William R. Fearon. William Heinemann (Medical Books), London. 10s. 6d. net. 8½ x 5½; x + 313; 1934.

In this introduction to biochemistry, planned to serve both as a textbook and as a laboratory guide, there is more emphasis than usual on the rôle of inorganic compounds in metabolism, and in viewpoint it is a little closer to physiology than to organic chemistry. Certain topics which require quantitative treatment and a background in biology in order to be presented effectively, such as the chemistry of blood, nerve, and muscle, are dealt with only briefly. The style of presentation and the selection of material are suited to college students beginning the study of

biochemistry, and the usefulness of the book as a laboratory manual is increased by numerous tables and diagrams of the color reactions and precipitation tests for important substances. There is an index and a short list of directions for the preparation of reagents.



PRACTICAL METHODS IN BIOCHEMISTRY.

By Frederick C. Koch. William Wood and Co., Baltimore. \$2.25. 9 x 5 $\frac{7}{8}$; vii + 282; 1934.

This manual is intended to introduce medical students to the important biochemical methods in current use and especially to familiarize them with the standard quantitative methods used for the study of body fluids. The explanations of the procedures are clear and detailed and the pedagogical value of the book is increased by discussion of underlying chemical principles involved in the analyses. There are numerous tables to facilitate computations and in an appendix about forty pages are devoted to directions for the preparation of reagents. This manual was written as a companion to Professor A. P. Mathew's textbook. It deserves a wide usage.



DIE HORMONE ihre Physiologie und Pharmakologie. Zweiter Band: Schilddrüse. Nebenschilddrüsen. Inselzellen der Bauchspeicheldrüse. Thymus. Epiphyse.

By Paul Trendelenburg. Julius Springer, Berlin. 45 marks (paper), 46.80 marks (cloth). 9 $\frac{1}{2}$ x 6 $\frac{3}{8}$; x + 502; 1934.

This, the last volume of a thorough and useful review of the literature of the hormones, treats those of the thyroid, parathyroids, pancreas, thymus, and pineal body. Upon the author's death in 1931 the publication of the manuscript was undertaken by one of his students, Dr. Otto Krager. He has changed the original manuscript only where more recent discoveries have made it necessary and has brought the literature up to the summer of 1933. There is an adequate subject in-

dex. The first volume of this work was noticed in these columns in Volume 5, page 121.



LE SÉRUM NORMAL: Récolte et Caractères Physiques.

By Denis Brocq-Rousseau and Gaston Roussel. Masson et Cie, Paris. 75 francs. 9 $\frac{7}{8}$ x 6 $\frac{1}{2}$; 363; 1934 (paper).

The authors have incorporated in this large volume the results of practically every study and observation made to date on the physical properties of normal blood serum. It is a most thorough compendium, clear and also critical; invaluable as a reference book. There is a bibliography of 57 pages.



TRANSPORTEURS D'OXYGÈNE. Actualités Scientifiques et Industrielles 102. Exposés de Physiologie.

By Marcel Florkin. Hermann et Cie, Paris. 12 francs. 10 x 6 $\frac{1}{2}$; 44; 1934 (paper).

This is an excellent review of the results of recent research on the respiratory pigments of the blood. The first chapter discusses their chemical constitution; the second, their physiological action; and the third, their distribution throughout the animal kingdom. A bibliography of a hundred titles, mostly in English and German, concludes the booklet.



DIE SPEZIFIZITÄT DER SEROLOGISCHEN REAKTIONEN.

By K. Landsteiner. Julius Springer, Berlin. 8.80 marks (paper); 9.80 marks (cloth). 9 $\frac{1}{2}$ x 6 $\frac{1}{2}$; iii + 123 (1933).

This is a useful brochure giving a summary of the work of the distinguished author and others on the antigens and phenomena of serological specificity, principally from the chemical point of view. It is amply equipped with bibliographies—general text-books, summaries and bibliographies,

lengthy literature lists on specific phases following each chapter, and works which have been published while this book was in press. An adequate index adds to the usefulness of the work.



FUNDAMENTALS OF BIOCHEMISTRY in Relation to Human Physiology. Fourth Edition.

By T. R. Parsons. William Wood and Co., Baltimore. \$3.00. $7\frac{1}{2}$ x 5; xii + 435; 1933.

Parsons' introduction to biochemistry remains the most interesting book on the subject available to beginners and interested laymen, and the fourth edition, brought as nearly up-to-date as is possible in such a rapidly growing subject, retains the narrative form that made the earlier editions so readable.



HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. Lieferung 427. Allgemeine und vergleichende Physiologie. Analysen von Gasgemischen. Gasometrische Methoden zur Analyse von Blut und anderen Lösungen.

By John P. Peters and Donald D. van Slyke. Urban und Schwarzenberg, Berlin. 16 marks. 10 x 7; 322; 1934 (paper).

Lieferung 427 has been translated from Volume II of the same authors' *Quantitative Clinical Chemistry*, and for the most part deals with the methods they elaborated for the analyses of blood gases.



DAS VERHALTEN VON BLUTKÖRPERCHEN SOWIE VON MIKROBEN IN ABGESTUFTEN ESSIGSÄURE-VANADATGEMISCHEN. Eine biochemische Methode zum Studium der Artspesifität.

By H. M. Jettmar. Urban und Schwarzenberg, Berlin and Vienna. 3 marks. $9\frac{1}{2}$ x $6\frac{1}{2}$; viii + 121; 1934 (paper).

A detailed presentation of the technique and results of the Oldeman-Bendien reaction on sera, blood corpuscles and microbes. Biochemists and microbiologists will find it a useful handbook.

SEX

THE ETHICS OF SEXUAL ACTS.

By René Guyon. Translated from the French for the first time by J. C. and Ingeborg Flugel. Alfred A. Knopf, New York. \$4.00. $8\frac{1}{2}$ x $5\frac{1}{2}$; xxii + 383 + xxvii; 1934.

M. Guyon is both a Frenchman and a hedonist. As a Frenchman he follows to their logical conclusion the principles which as a hedonist he professes. The Judeo-Christian ethics to which the Western world pays at least lip-service, true to its ascetic postulate of the vanity of this world, condemns sexual pleasure except for a grudging concession of the legitimacy of intercourse—for purposes of reproduction only—between a man and a woman over whom a magical formula has been recited. M. Guyon on the other hand concludes that sexual pleasures, including the so-called aberrations, are no more "immoral" than the pleasures of the table. His travels in the Far East have convinced him that a society which permits a free gratification of sexual desires is far happier and less neurotic than one which taboos them. The psychiatrists, he concludes, instead of basing their criteria of sexual normality on an objective, physiological foundation, have tacitly assumed that whatever is contrary to the local mores is pathological. Their attitude is thus not that of scientists, but of conventional moralists masquerading as scientists.

But psychiatry has gone even further than this in its abject and unconditional surrender to taboo. Without any attempt at verification it has accepted at their face value many of the prejudices and superstitions which have resulted from taboo. There exists a whole group of neuroses based upon fantastic and utterly unscientific notions: quite a considerable portion of humanity lives and has its being in a world that is peopled by illusory and imaginary entities—gods, prophets, saints, angels, devils, demons, ghosts—with whom they have daily converse, whom they call upon for help or counsel, whom they bribe or curse or worship, for whose sake they are ready to ruin both themselves and their families. Here, then, there is a formidable neurosis, which (unlike the manifestations of sex) is incapable of explanation in terms of normal, natural, easily verifiable, healthy processes. It is a neurosis that has sprung fully armed from its parent, the human brain. A triumph of artifact, it yet eludes the probing analysis of the psychiatrists, and almost entirely escapes their disapproval, pitiless as this may be in other directions. . . . So discreet a choice shows the measure of

confidence that we may have in the pronouncements of this science!

This is a book well worth reading and pondering, whether one is finally convinced by it or not. There seem to us under present conditions to be two objective reasons for limiting one's sexual pleasures. The first, briefly mentioned by M. Guyon, is that in a world where venereal diseases are fairly widespread the danger of infection from free intercourse is by no means negligible. The second, which he does not mention—no doubt he will deal with it in the sequel to be devoted to the question "as to what kind of organization, public and private, would appear best to meet the legitimate demands of sexual liberty"—is that so long as sexual pleasure sometimes leads to reproduction the care of the children produced must somehow be provided for. In an economic organization where the male has the upper hand the father of the child is the natural person to charge with this responsibility. But, as Strindberg pointed out, it is a wise father who knows his own child. The custom of chastity is therefore not a mere taboo but has the rational function of fixing at least the probable paternity of a child. However, with more effective and better known techniques of venereal prophylaxis and contraception these objections to free sexual expression will vanish. It is a striking testimony to the validity of much of M. Guyon's criticism that many of the clergy and other professional guardians of our conventional morality oppose venereal prophylaxis and contraception on that very account.



THE CASE FOR POLYGAMY or *The Case Against the System of Monogamous Marriage.*

By J. E. Clare McFarlane. *The Search Publishing Co., London.* 5 shillings net. 7½ x 4½; 159; 1934.

This book is not so much for polygamy, as usually understood, as it is against monogamy. Its essential idea is that there are too many old maids in the world, especially in England, and that something ought to be done about it. If the right thing is done then both the women and

the men will be satisfied, and that will make it unanimous all around. The author is a deeply religious and poetical fellow, filled to bursting with the zeal of the up-lifter. His arguments are extremely persuasive, and he draws support for them from the Bible with a skill matched only by such great theologians as Bishop Cannon and Brother Bryan of revered memory. But, alas, when he comes to the compounding of his eye-wash which is to cure the dreadful disease that festers in the body social, of which the etiological agent in his view is monogamy, his naïveté is positively shocking. For what he proposes, in all seriousness, is this:

Let each woman have the right to make an alliance with the man of her choice if he will have her and (if he be already married) provided his wife agrees to the arrangement. The value of this provision will be three-fold: it will indicate that the bond of love between husband and wife is so secure that the latter can with confidence permit another woman to share his affections; it will indicate also that the man is big enough to be entrusted with the affections of another woman; and it will ensure that prior to such an arrangement the women concerned have reached a basis of mutual understanding and confidence. . . .

Let each woman, therefore, be in a position to exercise, if she so desires, lawfully and without reproach, the function of motherhood for which Nature has endowed her. Let the stigma of illegitimacy be abolished from social life, and the children of every woman be accorded equal rights and recognition.

If there ever existed a freshman student of biology who did not sometime think of this scheme as an ideal solution of the problems of human behavior consequent upon the outpouring of gonadal hormones, we never heard of him. But later on in life he learns, even before his honeymoon is over, that noble as the idea seems to be there is a flaw in it. We think that Mr. McFarlane quite honestly does not know what that flaw is. If he *wants* to know he has only to ask any married woman. She'll tell him! And how!



THE SINGLE WOMAN. *A Medical Study in Sex Education.*

By Robert L. Dickinson and Lura Beam. *The Williams & Wilkins Co., Baltimore.* \$5.00. 9 x 5½; xix + 469; 1934.

While this is primarily a medical study of

certain phases of human fertility it is much more than a study of physiology and anatomy. It deals with the psychology of the patient, her emotional life, her conflict and her refuges from that conflict. Something over a thousand case histories make up the study which forms the second volume in a comprehensive investigation on sex experience and behavior. The work concludes with a brief summary and an appendix containing an arrangement of the material in tabular form. Tables of two control groups are included. The volume is indexed.



MORE LOVE AND SEX.

By X. Ray. *The C. W. Daniel Co., London.* 1 shilling net (paper); 2 shillings net (cloth). 7½ x 4½; 64; 1934.

This book, a sequel to the author's *Love: An Outspoken Guide to Happy Marriage* noticed in Volume 8, page 378 of this REVIEW, is a collection of detached thoughts and quotations, emphasizing the importance of a soundly biological attitude towards sex and the economic and traditional difficulties in the way of its attainment. There are a bibliography of one page and an index.



LE DEVENIR DU SEXE. *Actualités Scientifiques et Industrielles* 78. *Exposés de Biologie (Embryologie et Histogénèse).*

By Vera Dantschakoff. *Hermann et Cie, Paris.* 15 francs. 10 x 6½; 60; 1933 (paper).

A good summary of the present state of knowledge concerning the morphogenesis of sex.



BIOMETRY

AN INTRODUCTION TO STATISTICAL ANALYSIS.

By C. H. Richardson. *Harcourt, Brace and Co., New York.* \$3.00. 8½ x 5½; xi + 285; 1934.

This excellent text deals with tabular and

graphical representation, measures of central tendency, measurement of dispersion, skewness, excess, moments, linear trends, simple correlation (approached through the concept of regression), nonlinear trends, curve fitting, permutations, combinations, probability, the point binomial, the normal curve and the theory of sampling. Numerous exercises, an annotated list of books for supplementary reading, a four-place table of areas and ordinates of the normal curve and an index are also given. Since Professor Richardson feels that the student "will not comprehend fully what a formula means and what are its limitations unless he knows whence it comes and what are the assumptions underlying its development" he includes many derivations that do not presuppose a knowledge of more than high school algebra. However, many biologists and physicians shy like a skittish horse at any formula which appears at all complicated, however elementary it may be in reality. We fear that one glance at the Σ 's in some of his formulas would send such students galloping to the tall timber, from which it might be difficult to lure them back into the classroom.



✓ CALCULATION AND INTERPRETATION OF ANALYSIS OF VARIANCE AND COVARIANCE.

By George W. Snedecor. *Collegiate Press, Ames, Iowa.* \$1.00. 7½ x 5½; iv + 96; 1934.

An attempt is made here to clear up the technique of R. A. Fisher's known as the "analysis of variance." This is a very elementary calculator's hand-book with brief explanations, discussions, and notes on theory. The arithmetic examples are easier to follow than are Fisher's, but the method and terminology are the same. The author specifically states that the objective of the method is "the separation of the gross variation of the entire sample into two portions: (i) the variation among the means of the classes, and (ii) an average of the variation within the several classes." Yet the examples given use the "between class" variance as a test for homogeneity and not as a measure of

variation between means of classes. This is the same discrepancy between problem and illustration that exists in Fisher's work.



MANUALE DI STATISTICA. *Introduzione allo Studio Quantitativo dei Fatti Sociali. Volumes I and II.*

By Felice Vinci. Nicola Zanichelli, Bologna. 25 lire per volume. 10 x 7; Vol. I, vii + 230; Vol. II, 303; 1934 (paper). A textbook of mathematical statistics written for students of social sciences who have only a limited knowledge of higher mathematics. It is very well done and praiseworthy are the elegant algebraic demonstrations, in particular those relating to the theory of probability. Credit for the latter should be given to Castelnovo and Cantelli whom the author follows.

In appendices are given many useful tables, a chart showing the evolution of statistics (taken in part from Pearl), a list of statistical societies and journals, etc. There is an index.



VARIABILITY IN WEIGHT IN THE GOLDEN-CROWNED SPARROW. *University of California Publications in Zoology, Vol. 40, No. 5.*

By Jean M. Linsdale and E. L. Sumner, Sr. University of California Press, Berkeley. 9½ x 6½; 11; 1934 (paper).



PSYCHOLOGY AND BEHAVIOR

THE EFFECTS OF MUSIC UPON PULSE RATE, BLOOD-PRESSURE AND MENTAL IMAGERY.

By Alec Washco, Jr. Temple University, Philadelphia. \$1.00. 9 x 6; 269; 1933 (paper).

Thirty adolescents have been subjected to an experiment to determine the influence of different types of music on systolic blood pressure, on pulse rate and mental imagery. The principal conclusions

reached are that music of the type of a march, rhapsody or overture stimulates blood pressure and pulse rate, while a waltz, serenade or intermezzo causes a decrease. A survey of the tables shows that this is arithmetically true and possibly statistically, but there arises a doubt as to its significance. On the average the maximum increase observed is 10.4 mm. for blood pressure while that of the pulse rate is 8.9 beats. The maximum average reduction of blood pressure is 8.4 mm. and pulse 8.03 beats. Without adequate experimental control these and similar reported results obviously cannot be accepted, though they satisfy popular conceptions and appear true in individual cases.

The author is apparently a believer in the therapeutic value of jazz, for of the Rhapsody in Blue he writes: "This music suggests a treatment for Melancholia, anxiety and other forms of depression. It seems to react as a safety valve for depressed and suppressed nerves. It is one aid to the resolution of mental conflicts and at least temporarily alleviates worries." There is an extensive bibliography but no index.



TEXTBOOK OF ABNORMAL PSYCHOLOGY.

By Roy M. Dorcus and G. Wilson Shaffer. Williams & Wilkins Co., Baltimore.

\$4.00. 9 x 6; xiii + 389; 1934.

In 360 pages of text the authors attempt a complete review of the literature regarding the anatomy and physiology of the special sense organs, general neurology, psychology, psychiatry and psychotherapy. Useful as a textbook, the necessity for condensation results in generalized definitions and statements which at times may appear incorrect. On page 37, for example, one notes: "Among the symptoms of pathology of the vestibular sensations may be listed: *absence of nystagmus*, continuous nystagmus . . ." That this obvious *lapsus linguae* should have passed unobserved by one of the authors who has contributed special studies on the subject is surprising.

Worthy of special mention is the critical attitude that the authors have maintained in the exposition of the several psychological theories, though they are frankly disciples of Knight Dunlap. There are a bibliography of 313 titles and name and subject indices.



THE NATURE AND TREATMENT OF AMENTIA.
Psychoanalysis and Mental Arrest in Relation to the Science of Intelligence.

By L. Pierce Clark, Assisted by the Staff of the Psychoanalytic Sanatorium at Rye, N. Y., T. E. Uniker, Ethel L. Rourke, W. K. Cushing, Margaret C. Cairns. William Wood and Co., Baltimore. \$4.25. 9 x 6; xv + 306; 1933.

The author, well known as a psychiatrist, has been a valuable contributor to studies on the mentally deficient. In this volume he discusses the energies which have to do with the ament's (the mentally subnormal individual) immediate problem of coping with his outer world. A number of case histories are given in detail to show "the nature of the psychic barriers tending to impoverish mental growth, to indicate how these emotional fixations have come about, and to formulate their direct connection with mental arrest." Suggestions are made regarding the establishment of a sounder training treatment for the feeble-minded. On the basis of psychoanalytical findings the author believes that much can be learned in guiding the ament in the choice of his environment, his education and his future occupational activities. The work includes a glossary, a list of references and an index. Dr. Ernest Jones contributes a foreword.



A NEW PHYSIOLOGICAL PSYCHOLOGY.

By W. Burridge. William Wood and Co., Baltimore. \$3.00. 7½ x 5; vii + 158; 1933.

Basing himself on his experimental study of the rhythmic tissues of the heart Professor Burridge applies the theory of rhythmic action to the central neurons and

sensory end-organs, and attempts to correlate these processes with mental phenomena. In this way he arrives *inter alia* at a physiological formulation of Freudianism. Such deductions as his explanation of John Citizen's attitude to his wife in terms of the intensity and rate of neural rhythm may seem fantastic, but we must not forget that much of the physiological psychology of the more complex mental processes is still a matter of inference. If no one has observed the rhythm of a brain cell, it is equally true that no one has seen it explode. There is a bibliography of 25 titles and an index.



INDIVIDUAL PSYCHOLOGY, PSYCHIATRY, AND HOLISTIC MEDICINE.

By J. C. Young. The C. W. Daniel Co., London. 2s. 6d. net. 8½ x 5½; 62; 1934 (paper).

This little book consists of two papers delivered before the Medical Society of Individual Psychology, London, an organization devoted to "tempering the robust wind of Individual Psychology to the shorn and somewhat fearful lamb of modern medical practice." The gist of them is that laboratory technique, however elaborate, cannot take the place of insight into the patient as a whole. Unfortunately, since laboratory technique is easier to learn than insight, Dr. Young may have difficulty in converting the average medical practitioner.



STORIES OF SECOND-SIGHT IN A HIGHLAND REGIMENT.

By William Kirk. Eneas Mackay, Stirling, Scotland. 2s. 6d. net. 7¾ x 4¾; 123; 1933.

A collection of often weird, sometimes humorous stories, dealing (so 'tis said) with the personal experiences of Highland soldiers, comprises the present volume. Whether or not the yarns are true does not detract from the fact that some of them are interesting.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

AN INTRODUCTION TO LOGIC AND SCIENTIFIC METHOD.

By Morris R. Cohen and Ernest Nagel.
Harcourt, Brace and Co., New York. \$3.50.

8½ x 5½; xii + 467; 1934.

This admirable text aims to "find a place for the realistic formalism of Aristotle, the scientific penetration of Peirce, the pedagogical soundness of Dewey, and the mathematical rigor of Russell," and, we should say, succeeds very well. The authors agree with the traditional view of logic as the science of valid inference rather than as the study of how the mind works. In the treatment of necessary inference both the Aristotelian and the symbolic techniques are used. In the chapter on probable inference the authors reject the interpretation of probability as a measure of belief and adopt Peirce's interpretation of probability as the truth-frequency of types of arguments. The function of hypotheses and classification in scientific method is considered. Mill's methods of experimental inquiry are found to be neither methods of proof nor methods of discovery of relevant factors but are of value in eliminating irrelevant factors. The distinction, which the authors emphasize in their discussion of measurement, between additive characters such as weight and non-additive characters such as intelligence, which can only be ranked in a certain order, is one which is too often forgotten. In the chapter on statistical methods we have only two exceptions to enter: (1) While it is of course true that the computer cannot improve the accuracy of an arithmetic mean at will by carrying more decimal places it is *not* true that "the precision which is a result of numerical computation is fictitious unless the observations have been made with the same degree of precision." The errors of the individual observations will rarely be all in the same direction and consequently the mean of a large number of observations will usually be more precise than the individual observations on which it is based. (2) While the median is more stable than the mean for many leptokurtic distributions, for normal and

platykurtic distributions the mean is the more stable average.

Exercises, suggested readings and an index are given. Altogether this is an excellent book.



MODERN BREWING (Second Edition). *A Practical Hand Book of Contemporary Brewing Practice.*

Written and published by Carl A. Nowak,
Chemical Bldg., St. Louis. \$10.00. 9 x 5½; 389; 1934.

Mr. Nowak is a practical brewer whose aim is to explain brewing practice and the scientific principles on which it rests for the benefit of an industry that is relieved to find itself respectable again, and that is conscious of the lack of textbooks. His book is built around a translation of Heinrich Luers' *Grundriss der Bierbrauerei* which sets forth the fundamentals of beer brewing as practised in Germany and which provides the theoretical explanation for the fermentation processes. This is only the foundation, as it were. "For those not familiar with the methods of doing business in the United States, it may be well for me to call attention to the fact that, whatever the American does, is on a large scale, usually well financed, but must be done in a hurry. This accounts for many of the strange processes which the reader will find in subsequent pages of this book." (Probably this accounts for some of the strange tastes of the product, too.) Besides this odd disposition of the American business man there are a number of peculiarities of the American taste in beer to harass the brewer. For one thing, Americans insist on drinking their beer much colder than Germans or Englishmen, not only losing the aroma the *Brau-meister* has worked hard to put there but subjecting the beer to risk of turbidity. Now this would not be such a serious matter if Americans did not also have the barbarous custom of drinking beer from glass vessels instead of from opaque mugs in use on the Continent, and that makes it necessary to brew for optical properties as well as taste. American-grown barley has too much protein to yield the proper

shade of light beer unless to its malt is added some other carbohydrate. It is interesting to note that companies processing corn products showed more willingness to develop materials of this kind during Prohibition than they ever did before. Brewing beer in this country is a different thing from brewing on the Continent. Besides describing trade practices in this country the book is intended to teach the bare fundamentals of chemistry and bacteriology to brewers and their assistants. The book is provided with glossary, bibliography, index, and tables of various sorts.



MADEIRA. *Wine, Cakes and Sauce.*

By André L. Simon and Elizabeth Craig.
Constable and Co., London. 5 shillings
net. 7 $\frac{3}{8}$ x 4 $\frac{1}{8}$; 153; 1933.

SHERRY. *With an Appendix on Shippers and a Folding Map.*

By H. Warner Allen. Constable and Co.,
London. 5 shillings net. 7 $\frac{3}{8}$ x 4 $\frac{1}{8}$; 117;
1933.

These two volumes inaugurate a new series—*Constable's Wine Library*—likely to be of great value and interest to everyone concerned with the finer aspects of civilized living, provided the standard set by these initial volumes can be maintained.

Warner Allen has already a firmly grounded reputation as an expert on wines, and *Sherry* will further enhance it. It is the best treatise, considering the limitations imposed by its size, known to us on that greatest of high-powered wines. It is not a rhapsodical eulogy of a glorious beverage, but a pleasantly written, thoroughly erudite, technical scientific treatise on sherry, telling its history, how it is made, its varieties, etc. In short it is precisely the kind of book that will inform and entertain a person who wants to acquire a really sound elementary knowledge about sherry.

Almost exactly two-thirds of *Madeira* is devoted to recipes for cooking in which that wine is used, and for the accessories useful in giving Madeira parties instead of cocktail parties. For this part Elizabeth Craig is responsible. Wives of biologists (as well as of other gentry) will find this

part of the book extremely useful and in good part novel. The first third of the book, by Simon, is essentially a brief history of Madeira wines. It is entertaining enough, but of a literary rather than a scientific flavor.



THE SYSTEM OF BASIC ENGLISH.

By C. K. Ogden. Harcourt, Brace and Co.,
New York. \$2.50. 8 x 5 $\frac{3}{8}$; ix + 320;
1934.

With increasing international exchange of ideas the need for an international language becomes greater. In forty years Esperanto has got no great support, while English has become the most widely used of languages. Basic English is a system of 850 English words, to take care of all the needs of everyday living and for use as an international language for business, radio and science. It is a complete language which may be learned in a month. Important men of learning and of science in every country on earth give it support. This book gives an account of the system and examples of its use in everyday talk, in radio, newspapers and motion pictures, in business, in science, in economics and political questions, in religion, and in stories. The present account is in Basic English.



LOGIC IN PRACTICE.

By L. Susan Stebbing. Methuen and Co.,
London. 2s. 6d. net. 6 $\frac{3}{8}$ x 4 $\frac{1}{8}$; ix + 113;
1934.

This excellent little book is, as the title implies, concerned with the practical technique of sound reasoning. While a brief, but clear, discussion of logical forms is given, equal attention is paid to the symbolic character of language and the danger of ambiguity in the use of the symbols. From the frequency with which Mr. Roosevelt replaces Socrates in the examples the reader may draw the probable inference that the English find the New Deal a subject of interest. A brief bibliography and an index are provided.

THE QUARTERLY REVIEW of BIOLOGY



RADIATION GENETICS

By C. P. OLIVER

University of Minnesota

I. INTRODUCTION

THE effectiveness of high-frequency radiation in the production of heritable changes in abundance, reported by Muller in his work with *Drosophila* and corroborated by the independent work of Stadler with plants, opens to the geneticists a method to speed the investigations of their problems. Some irradiation had been done earlier than the reports by Muller and Stadler; but it was not until after 1927 that an intensive use of radiation in genetics occurred. Many plants and animals have been subjected to irradiation, and in most of them genic and chromosomal changes have been induced. Irradiation not only supplies geneticists with a tool for the investigation of old problems, but also opens to them new problems and new methods of advance.

II. REGIONS OF THE SPECTRUM INVESTIGATED

Investigations have not been confined to natural (earth) radiation, x-rays and radium emanations, but have been carried into the low-frequency range.

Supersonic vibrations

Drosophila males were subjected to 285,000 vibrations for 25 seconds. In 26,135 possibilities appeared 57 abnormal individuals, including 5 with mottled eyes. Only the mottled eyes were hereditary. The results are inconclusive that the variants were caused by the treatment, but it is definitely shown that the supersonic vibrations used here do not produce effects comparable to those produced by x-rays and radium (110).

Electricity

Treatment of *Drosophila* males in a field between two concentric copper cylinders with a current of air passing through the space between the cylinders, 33,000 volts at 60 cycles, was given in dosages from 1 to 30 minutes. Treated individuals showed the effect; but no lethal mutations were induced, although some variants were observed (116).

Electrostatic

Drosophila males were subjected to 225,000 volts at a frequency of an oscillat-

ing current of 1,225,000 cycles per second for one minute. Six hundred and ninety matings were made to observe for lethals, but no mutations were observed (116). After being subjected to an oscillating current of 6,000,000 cycles per second, wave length 200 meters, time 30 seconds, *Drosophila* males showed the effect of treatment. Only 35 per cent of the individuals were fertile. In 1607 cultures, no translocations or visible mutations were induced and the lethal-mutation rate was not significantly greater than that of the controls (241).

Electromagnetic

After exposure of pollen, a few recessive mutations were observed in maize. Ear shoots exposed between poles of a magnet 24 or 36 hours after pollination for 15 to 45 minutes produced endosperm mosaics two or three times as numerous as did controls. The frequency of mosaics increased with exposure increase, but not proportionally. Induced translocations also were indicated (253). Stadler (262) also reported that the method induces mutations in barley.

Ultra-violet

A quartz mercury arc with *Drosophila* under a quartz cover and cooled by iced air was used with treatment given to eggs, larvae, and adults. Earlier results by Altenburg (2) suggested that the method is not as effective as x-rays, but later results were found to be significantly effective. Thirty-four mutants were found in 11,502 treated to 3 in 11,162 control individuals (3, 4). Permanent and temporary modifications in *Chilodon* after treatment were observed by MacDougall (133, 134). Middleton induced a heritable change in the fission rate of *Paramacium*. Stubbe reported (274) that about 85.7 per cent of treated *Antirrhinum* pro-

duced altered F_1 as against 2.07 per cent in controls. This method has also been used by Goodspeed.

Grenz rays

Ultra soft x-rays generated at 7 KVP (262) or 5-10 (274) are sufficient to induce mutations. The induced mutation rate was increased 300 per cent over controls in *Antirrhinum* (277). Goodspeed has also found the method effective. The Beta rays of radiothorium and Cathode rays are also effective in the induction of mutations (262, 135).

III. RESULTS OBTAINED WITH X-RAYS AND RADIUM

Chromatin distribution

The percentage of primary non-disjunction in *Drosophila melanogaster* is significantly increased by x-radiation of the female (5, 6, 137, 138, 139, 143), and by radium treatment (164). The exceptions appear during the decreased fertility of females (143) and from eggs deposited the first six days after treatment (137, 234).

Aging eggs in the female before treatment increases the percentage of non-disjunction, although aging alone will not cause an increase. The frequency increase is gradual up to the eighth day, after which a decided decrease occurs, probably due to the fact that virgin females deposit their mature eggs in the eighth day (219, 234).

Exceptional males occur more frequently than exceptional females (139). Anderson (10) reported 631 exceptional males to 113 exceptional females among 57,877 offspring from the x-rayed *Drosophila* mothers. Patterson and coworkers (234) observed 330 exceptional males to 46 females in 90,000 offspring in the treated series and 55 non-disjunctional males to 8 females in a like number of controls. With *Dro-*

sophila virilis, Demerec and Farrow (44) reported a greater variation between the male and female ratio. In the treated series, 338 exceptional males to 17 females appeared in 65,809; and in the controls 23 to 2, in 37,188 offspring. Only two of the tested primary exceptions gave a high frequency of secondary exceptions and of crossing over (6, 9), and one of these has been found to involve a translocation (51). Age as shown by two successive broods does not alter the percentages of secondary exceptions in these lines (8).

Crossing over in the eosin-miniature region of the X-chromosome of *Drosophila* decreases in frequency as a result of x-ray treatment (140) and increases in the regions on both sides of the spindle fiber attachment of II (148, 149). Radium influence is similar to that of x-rays (235). The effect on crossing over is not inherited (150), and is due to the direct action of x-rays on the germ cells; no increase occurs unless at least the posterior half of the body is treated (146). A regional differential susceptibility to x-rays (II and III) was observed by Muller (165) who also found that the X does not differ from II or III if corresponding regions with relation to the spindle fiber are compared (166). Stadler (255) detected no influence of x-radiation on crossing over in maize. Combinations of temperature and irradiation (temperature before and after treatment) cause variations in the frequency of crossing over (126). Mavor and Svenson (151) have also made a comparative study of the influence of temperature and irradiation on crossing over.

Lethal and visible mutations

Antirrhinum after radium treatment developed abnormalities that were inherited by vegetative reproduction (265, 266); tissues were modified (268); and some variants apparently were results of gene

mutations (269). X-radiation altered 87 per cent of the treated parents to 2 per cent in controls (274).

Bacteria seem to be more stable. Irradiation caused no variation in *B. coli* and only a tendency towards lack of ability to produce red pigment in *Erythrobacillus prodigiosus* (37). Other fungi have been investigated by Holweck and Lacassagne (*Saccharomyces*), by Nadson and Phillipov who have been able to select new and stable races, and by Svenson (*Saprolegnia*) who found negative results.

Barley mutants were observed in tillers (53 in 2800 treated head progenies, none in 1500 controls) after x-ray and radium treatment (254, 258). The tested mutants bred true, but among them no clear case of dominance was observed (258).

Chickens that developed from fertile eggs subjected to x-rays (120) showed the influence of the irradiation.

After x-ray treatment of cotton seeds, dwarfed plants and in other cases cotyledon and plant mutations appeared, some of them heritable (117, 118, 119). Induced variations of seeds and lint were also observed by McKay and Goodspeed.

Datura subjected to radium treatment had induced both gene and chromosomal mutations (11, 23, 64). Treatment of pollen induced lethal gene-mutations that caused half the pollen to be eliminated in male gametophytes; however, the genes may be inherited through the female gametophyte (28, 30, 31, 33) but pollen abortion also may be due to induced chromosomal abnormalities (34).

Drosophila funebris males after x-radiation gave a higher frequency of sex-linked lethal and visible mutations, the latter for the most part of wings and bristles (280, 281). *Drosophila obscura* responds to irradiation (162, 242), and *Drosophila melanogaster* has been used repeatedly in irradiation experiments. Muller reported

an increase in the mutation frequency of 15,000 per cent when sperm were subjected to x-rays; five lethal mutations were found in 6016 control chromosomes; 59 in 714 chromosomes given a T_2 dosage, and 142 in 1177 T_4 chromosomes (168, similar ratio 170). Induced changes involve all gradations of lethality and visibles; those resembling known mutants, at new loci, new genotypes but old phenotypes, and many extreme allelomorphs (167, 168, 174). Weinstein (295), Hanson (93), and Demerec and Anderson corroborated the effectiveness of x-rays in producing changes. Visible mutations, new and old types, were increased 1200-1600 per cent by Grüneberg (86), and have been reported by Hanson (94), Mavor (147), Serebrovsky and Dubinin (244) and other investigators. After radium treatment, 204 induced mutations were observed in 14,480 offspring by Hanson and Winkleman. Mutations also are induced in somatic tissue by x-rays (78, 217, 283). Patterson (217) observed 42 variant areas of the eye among 1473 treated to none in 1789 control individuals (also see 218, 219). Dominant eye colors in *Drosophila melanogaster* appeared for the first time in irradiation experiments. Weinstein (295, 296) observed the first dominant eye-color (typical, eversporting type). Oliver (198, see also 174) found a solid color, non-eversporting, but connected with a chromosomal alteration. Van Atta (293, 294) detected a dominant due to a definite gene (no connection with a chromosome aberration).

Grape fruit seeds exposed to x-rays developed into plants, some of which showed seedling variations (161).

Habrobracon mutants were found by Whiting (301, 303, 304, 305) and by Dunning as a result of x-ray treatment. Induced non-inherited freaks and mutations occurred after larvae treatment (297,

299) and after adult male (36) and female (25) treatment.

Mice subjected to x-ray treatment produced descendants among which abnormalities occurred (130, 131), and the abnormal eye individuals show no variation in chromosome number or morphology (210). Variant types observed by Dobrovolskaia-Zavadskaia were interpreted as not induced by the treatment. Snyder (251) found no induced visible modifications in rats.

Nicotiana has been used extensively in irradiation experiments, and as a result of x-ray treatment developed vegetative and floral changes and gene mutations (68, 70, 73, 74, 76, 77).

Oenothera buds after being subjected to radium treatments developed atypical forms (26).

Sorghum responded to x-ray treatment, and four induced recessive mutations bred true (Horlacher, Karper and Quinby, reported for 201).

Tomato leaf and floral abnormalities were observed by Johnson. McArthur and Lindstrom exhibited recessive plant characters and also seedling characters that were induced by x-ray, radium and cathode treatments (135).

Triticum variant types were observed by Delaunay (41, 42), Stadler (see VI), and Sapehin.

Other organisms are given under subsequent headings.

Chromosomal mutations

Translocations are induced with x-ray treatment of *Drosophila melanogaster* sperm (167, 168, 169, 295), with a frequency equal to that of gene mutations (170, 178, 179, 199, 200). Oliver reported 21 lethals, 16 CA (most being inversions), and 17 translocations occurring in 105 individuals from t_{18} treated parents, and 18 lethals, 13 CA, and 10 translocations all involving

the X in 411 offspring from t_4 treated parents (200).

Most induced translocations are probably of a simple type (214). This type has been observed by Dobzhansky and others working with *Drosophila*, by Nabours and by Robertson with *Apotettix*, and by Blakeslee (23) with *Datura*. Of the thirty translocations studied in maize, none were simple; all were reciprocal or involved a deficiency at the point of translocation (152). Mutual or reciprocal translocations have also been observed in *Drosophila* (24, 51, 54, 57, 173, 278, 294), and abnormal configurations were explained as due to reciprocal translocations in *Datura* (20, 23), and in *Circotettix verruculatus* (109). The more complex translocations may involve a deletion of one chromosome (II to Y, 50, 51, 53, 236; X to IV, 185; X to III, III to X, 198, 200), or multiple fragmentation, probably inversions in the donor or recipient chromosome (51, 198, 200, 294).

Homozygous translocations observed in *Drosophila* usually prove to be lethal or sterile, or exhibit abnormalities (52 and earlier, 174, 178, 179), although some do not (47). Bergner and coworkers (21) also reported a homozygous translocation in *Datura* that breeds true. Individuals heterozygous for a translocation usually are normal in appearance, but in some cases visible effects accompany the fragmentation (174). Dobzhansky (54) and Van Atta (294) reported visible changes that are inseparable from a point of breakage.

Chromosomes may fragment or have a fragment attached to any point (48, 50, 170, 178, 183, 189, 295), and not always at constrictions (49, 214), although chromosomes may give way more readily at constrictions (128). The displaced fragment is usually attached to the end of the recipient chromosome (49, 51, 232), but

the attachment may be along the side (57, 278) or the piece may be inserted (198, 200, III into X near *ec*). Any or all chromosomes may be involved in a translocation, with little or no preference except as a function of the length of the chromosomes (170, 178, 179). Most observed translocations are interchromosomal, but intra-chromosomal types may occur. Of the latter type, a fragment of X was deleted and attached to the right end of X (59, 244).

Inversions, deletions, and deficiencies (not necessarily translocations) have been observed in *Datura* (20), maize (67, 258, 261), *Secale* (128, 129), and *Drosophila* (183, 214, 244 and others), including inversions that cause a V shaped chromosome to have a terminal fiber attachment (202, 294).

Chromosomal irregularities were induced in *Datura* with a frequency of 10 per cent (20), and some of the new types cause aborted pollen (34). Lost satellites and fragmentations have been observed in *Crepis* (128, 189) and *Vicia* (128). Frequent rearrangements and losses were reported in maize (261). Variations in number and shape of chromosomes occurred in *Triticum* (41). Chromosomal irregularities were induced in *Nicotiana* (77), with fragmentation, non-disjunction, and duplication of fragments (68, 70, 75). Variations in the number of chromosomes as a result of treatment occurred in *Datura* (64), *Nicotiana* (68, 71, 73), and tulip (157, 158); but in maize no evidence of tetraploidy or duplication of whole chromosomes as a result of irradiation was observed (261).

Mosaic regions

If *Drosophila* eggs or larvae are treated with x-ray, variant colored areas appear in the eye. With a treated homozygous red female, no white areas were observed

in 217 individuals; with a female heterozygous white, 34 areas in 666; males not white, 8 areas in 807; and in the control males and females, none (217). Similar but larger ratios were observed by Patterson (218) and by Timofeeff-Ressovsky (283, 284). The latter also reported changes of eosin to white (2 in 1407), of eosin to red (1 in 1407), of white to red (1 in 2986), and of white to reddish allelomorph (1 in 2986). Patterson (218) also found mosaic areas for other traits, many of which have been exhibited (230). The greater frequency observed in females is explained as due to breakage of the X (217, 218, 219). The use of special stocks determined that in many or most cases the areas are due to fragmentations, and not to the elimination of the whole X (220). Gowen (78) also found the action in producing mosaic regions to be local as to III, the affected areas involving but one of the colors (st, ca) investigated. Mosaicism in *Habrobracon* was reported as a result of binuclearity (85, 300).

Germ cells of *Drosophila* treated with x-rays may develop mosaic individuals for parts of the body due to the loss of IV (49), or for mottled eyes involving the locus of white on X, or eversporting variegated eyes (see VII). *Habrobracon* after x-ray treatment had variant regions of eyes and wings (5 in 1721 treated, 6 in 8258 controls, reported in 297) but mosaics occur only in heterozygous females as a result of binuclearity (299).

In maize, treated embryos develop into chimeras; but if treatment is given on the first and second day after pollination the whole plant shows an absence of dominants. The areas are also observed if pollen is treated (258). Mosaic endosperms occur (255). The size of the variant area depends upon the time after fertilization that treatment is given (258). In a 20-fold increase as a result of irra-

diation, the mutated areas seemed to be due to a lack of a piece or all of a chromosome, as shown by the loss of dominant markers (255, 258, 261). Cotton was reported with splotched areas of virescent yellow and of green-white due to cytoplasmic disturbance or to abnormal chromosome behavior, and angular areas that were probably nuclear changes (117, 119). Heterozygous barred and also black-white chickens developed mosaic regions (15 areas in treated, to 4 in an equal number of controls, reported in 120). In mice, white areas replaced color (90), and such areas may be used as an index of sterility (125). Mosaic areas have occurred in *Nicotiana* as a result of treating germinated seeds and seedlings (68).

Sex mosaics

All of 23 sex mosaics found in *Habrobracon* by Dunning were sterile. In *Drosophila*, Mavor (144) reported 4 sex mosaics in 68,186 treated, and none in 65,128 control individuals. Of the 4, the treated X had been eliminated twice and the untreated X twice. Patterson determined that the sex mosaics were caused by elimination of the treated X in 32, and of the untreated X in 17 cases. Of the latter, 15 came from treated eggs and 2 from treated sperm. From these results Patterson (221, 223) concluded that if the sperm is treated, the treated X is more apt to be eliminated; if the egg is treated, either X with an equal frequency. If eggs are treated, generally the whole chromosome is eliminated and the mosaic is of the half-and-half type. This type alone is increased over that found in controls by irradiating the sperm cells (231).

Fertility and viability

Radium treatment of *Antirrhinum* may leave only females fertile, or neither sex fertile (267, 269). *Habrobracon* as a result

of treatment has a less number of females (60, 302, 25). In *Drosophila*, the decrease in fertility of treated males is interpreted by Muller as due in part to dominant lethals (167, 168), and Stancati using *Habrobracon* determined that the absence of biparentals is due to zygotic dominant lethals and not to an absence of viable sperm. Treatment of *Drosophila* females causes a decrease in fertility; but a partial recovery occurs, and the new eggs show a high proportion of mutant genes (167, 168). The effects of x-rays and age on fertility have been found by Patterson and coworkers (234) to be manifested chiefly on the fully formed eggs, no effect being apparent on immature eggs.

Snyder (250, 251) and Snell (248, 249) found that x-radiation produced infertility in rats and mice. The latter reported that the litters sired during the early fertility period were reduced in number, not as a result of a lack of motile sperm, but due to genetic changes lethal to embryos. Strandkov obtained similar results and conclusions with guinea pigs.

With treated dry or soaked seeds of *Nicotiana*, the initial rate of germination is retarded, but only temporarily (68), and treatment does not lower the percentage of germination of good dry seeds of cotton (117, 119).

The effect of irradiation upon fertility and viability may also be observed among the offspring of treated individuals. In *Drosophila* the decrease is explained by Muller as due in part to dominant sterility genes (167, 168). The condition in maize is generally due to deficiencies and translocations rather than to gene mutations (258, 261).

IV. RESULTS WITH VARIATIONS IN TREATMENT

Variation in the duration of x-ray treatment of *Drosophila* males was found to

produce a like variation in the mutation rate, although with the two dosages used the small numbers did not show the results proportional to dosage (93, 167, 168, 295). With a series of 5 regular steps, each dosage increase showed a significant increase in the induced F_2 lethal mutations (197, 200). Similarly an increase was observed with three dosages by Serebrovsky and Dubinin, by Efroimson for each series (hard rays, soft rays, and with Coolidge tube), and by Dunning with dosages between 1200–8000 R in an investigation of *Habrobracon* somatic abnormalities. The number of mutated somatic areas in *Drosophila* increases with a like variation in dosage, but size of the areas depends upon the age of the treated individuals (217, 218, 219).

Stadler (254, 256, 258) observed an increased frequency of mutations in barley with an increased x-ray intensity. Similar results were observed, but no actual measurements made, with cotton (117). Stubbe (277) reported that an increase in r-units (doubled each time) causes an increase in the percentage of gene mutations in *Antirrhinum*, but that the variations fluctuate irregularly.

Radium behaved similarly in that an increase in dosage applied to pollen caused a significant decrease in the rate of *Datura* pollen-tube growth (29). It has also been reported with *Drosophila* that as radium rays were screened with increasing thicknesses of lead, the percentage of F_2 lethals induced in males decreased consistently (95, 97).

An increase in voltage in x-ray treatment of *Drosophila* males (40 to 100 KV) caused an increase of F_2 lethals; doubling the voltage quadrupled the number of lethals (105, 107). The mutation rate in barley also increased with voltage increase (254).

Crossing over irregularities and translocations increased with the duration of

treatment to which *Drosophila* males were subjected (295). With two doses (one double the other) the frequency of translocations involving the X and crossing over irregularities of X for the higher dose occurred with a frequency twice that for the lower dose (199, 200). Treatment of young ears of maize with seven graded doses caused a graded increase in the number of deficiencies as observed in mosaic endosperm (67, 261).

Non-disjunction frequency in *Drosophila virilis* after x-ray treatment of the female increased rapidly and significantly only up to 1200 r-units, after which the increase was not so rapid (45).

That fertility progressively decreases with dosage increase has been observed in the number of offspring from treated *Drosophila* males and females (167, 295), and in a comparison of the mortality of eggs and larvae, and pupae (93). Snell found a similar decrease with mice. With eight graded steps for treated *Drosophila* females, fertility did not decrease rapidly until high dosages were used (45). A similar condition was observed by Oliver when males were treated in five graded steps (reported for 201). An increase in x-ray dosage causes a decrease in fertility of *Habrobracon*, whether males or females are treated (25, 60, 299, 302), the average number of progeny decreasing with increase in dosage. Three extremes of dosage were found by McCrady to produce three degrees of sterility in *Habrobracon* and three variations that may be observed cytologically. In *Datura* a marked difference in seed output per capsule and of plants obtained was observed with dosage steps of 0.16 millicurie hours (29).

Equivalent dosages (intensity) differently applied do not vary the results. Discontinuous treatments with measured intensities were used on barley, and an increase in the mutation rate was observed

with added dosages (254). Serebrovsky and Dubinin found an increase in the mutation rate in *Drosophila* whether dosage was intermittent or continuous. In a test by Patterson (224) of continuous and spaced treatments with the total duration equal, no significant variation in the results occurred. Different x-ray voltages in equivalent treatments of barley seeds (KV from 40-116) induced mutations with an equal frequency (258). High intensity of radium treatments for brief, or low for long periods gave equivalent results with *Drosophila* (102, 103). In a comparison of x-ray and radium effectiveness based upon a study of the seed yield per capsule for *Datura*, Buchholz and Blakeslee (32) found the relative effectiveness of the two treatments to be comparable. Packard (206) has found a similar effectiveness for the two methods in an investigation of their biological effect.

Variations in conditions during treatment

Barley seeds soaked 7 hours in M/5 solutions and x-rayed 15 hours later were found to have a higher mutation rate as a result of the chemical impregnations (254). *Drosophila* males subjected to sulphuric ether during radium treatment gave an increased sterility and lethal mutation rate (101) as a result of the anaesthetic.

Results obtained when *Drosophila* males were given the same dosage (2300 r) but treated at 34°C., and at 8°C., indicate that temperature will not alter the effectiveness of irradiation (173). Stadler (256, 258) also found no variation in the mutation rate of dormant or germinating barley seeds irradiated at various temperatures (10-50°C.).

The relation between other physiological conditions and the mutation rate has been investigated in plants and animals. Mutations may be induced in dormant seeds, but at a lower rate than for

similarly treated germinating seeds. At high dosage, however, the rate for dormant seeds is as high as for germinating seeds at their limiting dosages (256, 258). The average yield of mutations per Roentgen unit in germinating seeds is about eight times that in dormant seeds (256, 262). This difference is not a question of water content. The rate for seeds soaked before treatment, but not germinating, is no higher than for dormant seeds (258). Chromatin in any metabolic condition of the cell, from dry seeds to mature sex cells, can by appropriate treatment with x-ray or radium be quantitatively or qualitatively altered, but dry or soaked seeds are more resistant in *Nicotiana* (68), cotton (117), barley (256, 262), and *Antirrhinum* (275). Muller (173) postulated from small numbers that the metabolic rate in *Drosophila* females (fed as against starved; impregnated against virgin) probably does not alter mutability significantly; but Hanson and Heys (101, 104) observed reduced sterility and mutability as a result of starvation before treatment.

Variations in conditions before and after treatment

If seeds are steeped for 14 hours, tolerance decreases to half that of dormant seeds. The first half hour of aeration again decreases tolerance by half; but the decrease is less marked during the next $4\frac{1}{2}$ hours. Mutability increases slightly during the first two periods and then increases rapidly (262).

Germinating seeds subjected to various temperatures (7 to 37° for 24 hours following treatment) and dormant seeds (—80 to 38° for 24 hours after, and 5 to 38° for weeks after) have their mutation rate unaffected (262); however, *Habrobracon* males are more fertile if kept at low temperature for 14 days after treatment (302).

Aging of *Drosophila* sperm before treatment will not alter the induced mutation frequency (167, 288), nor will the rate of lethal mutations be altered if treated males are held as long as 16 days before mating (108, 98). In successive broods every 7 days after radium and x-ray treatment no change in the mutation rate occurred until the fourteenth day, after which there was a sudden drop (98). No significant change in the rate of sex-linked lethals occurred for 12 days in successive matings of males to virgin females every 4 days (108) and broods every 5 (288) or 6 days (61). Schapiro found that the percentage of translocations (II, III, IV) in successive matings to virgin females approximately every 6 days decreased rapidly after 16 days. On the other hand, Sidoroff observed about as many lethals in II during the second as during the first 14 days. Mutations occur in dormant seeds whether or not they are planted immediately after treatment, but the heavily treated seeds decrease in viability during storage (256, 258). Cotton seeds that had been stored for two years before treatment seemed to be more susceptible to x-radiation (117). Aging *Drosophila* females before treatment does make them more susceptible to irradiation in the induction of primary non-disjunction and in the breakage of the X-chromosome (219, 234).

V. SELECTIVE ACTIONS OF X-RAYS AND RADIUM

Sex-ratio

Irradiation of *Drosophila melanogaster* males causes a deviation in the sex-ratio in favor of more sons (16, 17, 61, 93, 168). This is explained as due for the most part to dominant lethals induced in X, the Y being inactive (61, 168). Barth (16, 17) found that if the males are mated to attached-X females, less sons than

daughters appear, in either case a differential susceptibility of X and Y sperm, resulting in a deficit of X sperm. With *Drosophila obscura*, a low ratio of female to male was reported by Morgan, Bridges, and Schultz (162), due possibly to many types of chromosomal aberrations (242). Treatment of *Habrobracon* females reduces the ratio of female offspring, probably due to injury to the sperm in the seminal receptacles (25, 302), or to induced dominant lethals (85).

On the other hand irradiation of *Drosophila* females causes no marked difference in the sex-ratio, and does not affect the potentiality of eggs to produce male or female (143). Neither is the sex-ratio altered by treatment of eggs and larvae (218); consequently, the mortality of larvae is considered by Muller (173) to be chiefly non-genetic.

Stage of maturity of sex cells

A differential effect upon early and later germ-cell stages is observed in treated *Drosophila*, with a less effect upon early male sex cells. This conclusion is based upon the observed decrease in the percentage of mutations that occurs twelve to fourteen days after treatment (see IV). The observed differential effect is explained as due to the fact that chromatin in mature male germ cells is more easily affected, or that germinal selections or selective multiplication occur against the affected immature cells (173, comparison of mature sperm as against larvae; and 108, 246, 288, differences in mutation rate over a length of time). Patterson (231) found evidence for a selective effect in the decided drop in fertility that occurred on the fourth day after irradiation. Strandkov suggests that lethals may be more readily produced in mature guinea pig sperm, but spermatogonia may also be affected. The susceptibility of immature cells is sup-

ported by the fact that reverse mutations of forked to not-forked occurred as frequently from treated *Drosophila* larvae as from treated sperm (232). In fact, mutations may be induced in all portions of the genital system of either sex (167, 168, 170). This is also suggested by the appearance of similar mutants in the same culture (217, 232).

In *Nicotiana*, the indications are that the stage of maturity of the sex-cells has little relation to the effectiveness of x-radiation (68); but in *Habrobracon*, the less mature eggs are sterilized more readily (302). A difference in the response of Cladoceran eggs in the brood pouch and the immature stages has also been referred to (194).

Sex

Mutations are induced in *Drosophila melanogaster* whether sperm or eggs are treated (167, 168, 170), but gene and chromosome irregularities occur more frequently in sperm than in oocytes for a given dose; and the ratio of chromosome to gene variants is greater in males than in females (173). Similarly in *Drosophila obscura* the effect of treatment is more noticeable on the males (162, 242). Somatic mutations occur more frequently in *Drosophila* females than in males (see III). A comparison of the response at the same stages in the life cycle indicated to Moore (160) that fertility is decreased more by treatment of males than of females. In *Antirrhinum* the gene mutation rate is higher in males than in females; but the rate of variation is higher in females (274, 277). *Habrobracon* male larvae are more susceptible than female larvae (299).

Other conditions

The mortality of treated eggs and larvae of *Drosophila* is high but older larvae are more resistant to irradiation (145, 218),

and the resistance increases after 30 hours of pupation to equal that of the adult (145). Woskressensky also found the adult flies to be more resistant, as did Hey with the bean weevil. A possible susceptibility of chromatin during a peculiar physio-chemical condition is seen in the multiple mutations per treated cell, and in the fact that treated adult males gave 111 abnormal F_1 males among 2964, to 20 among 2651 treated larvae 3-4 days old (173).

VI. GENETIC PRINCIPLES DETERMINED

Relation of dosage to genetic effects

The frequency of induced mutations is directly proportional to the intensity of treatment. In the plant group it has been found that with dormant or germinating seeds of barley, the mutation rate is proportional to x-ray intensity (256, 258), to the amount of radium treatment, or of any given radiation (262). Proportionality does not apply to the frequency of induced defective maize seeds, for the rate rises sharply with higher dosages (261). Variations in *Antirrhinum* are not induced proportionally to x-ray intensity (274, 277), although gene mutations are (277). Leaf variegations in cotton follow roughly the proportionality rule (117). But with *Datura*, an increase from 2 to 4½ hours failed to result in an orderly increase in chromosome abnormalities, aborted pollen, or obvious abnormalities (22).

In *Habrobracon* "Shot" wing varies in degree and percentage with dosage, probably requiring a physiological explanation (299). The close relationship between the induced mutation frequency of *Drosophila* and intensity was determined by Hanson; the rate of induced mutations and the amount of ionization formed equivalent curves (95, 97). Proportionality holds true with variations in x-ray voltage (105,

107); and with variations in the duration of x-ray treatment (197, 200), the observed mutation rates approach the calculated percentages based on proportionality. Serebrovsky and Dubinin concluded that with dosage doubled the mutation rate will be doubled. Efroimson found this to be true for the three series studied, although the intensity required to produce a mutation may vary for the three. Intensity governs the mutation rate whether treatments are given continuously or intermittently (224), or whether two unequal radium intensities are given with time variations to produce equal total intensities (102, 103). Lacassagne and Holweck also found this to be true with yeasts. Packard (204, 205) made use of the biological effect as a measure of dosage.

Induced sterility in *Drosophila virilis* is not proportional to dosage. A rapid increase in sterility occurs near 2000 r-units if the females are treated (45).

Use of lethal mutations for gene mutation rate

It is probable that all lethal mutations are not point mutations, but that some are connected to, and due to chromosomal aberrations (168, 296), or definite deficiencies (227). Calculations indicate that approximately 25 per cent of the induced lethals are due to chromosomal irregularities (200). These lethals connected with chromosomal alterations do not increase in frequency in proportion to dosage, but increase rapidly with the heavy dosages (197, 200).

The F_2 lethal method used with *Drosophila* does not show all the induced mutations, but only the mutated chromosomes, due to chance grouping of mutations at higher dosages (61, 244). Grouping occurs for given dosages with the frequency expected as a matter of chance, if allowance is made for the lethals due to

chromosome breakages; also all F_2 lethals are found not to be lethals in the next (F_3) generation; however, this variation is about equal for the different dosages (200).

Relation of intensity to chromosome irregularities

That x-rays increase the frequency of inversions as well as lethal mutations in *Drosophila* has been reported by Serebrovsky (243), Muller (167, 168, 169, 170), and others. The direct proportionality of the frequency of induced sex-linked inversions and translocations for *Drosophila* was determined by Oliver (199, 200), and of deficiencies for maize by Goodsell and by Stadler (261). Non-disjunction occurs proportionally to the increase in r-units only for lower intensities (45).

Relation of wave-length to mutations

Through a wide range of wave-lengths, Stadler (258) found that x-rays are about equal in power to cause mutations in barley. Using *Drosophila*, Hanson (107) and also Gowen and Gay (80) concluded that it is a question of quantity rather than quality; but Efromson using equal r-units (1000) for the different series studied found a slight variation in the induced lethal results. *Antirrhinum* is more susceptible to treatments of 30-50 KV than to harder or softer rays, as a consequence of the favorable conditions of absorption (277). Packard and Lauritsen in their measurement of *Drosophila* death rate found that different wave-lengths through a wide range are effective.

Natural radiation and spontaneous mutations

In the experimental results, no threshold dosage has been found below which mutations are not induced. It seems prob-

able that if the intensity is carried to that of the natural (earth) rays, the mutation rate will be proportional to that intensity. Low (natural) intensities do seem to induce mutations proportional to the ionization strength. With two measured intensities, one double the other, Babcock and Collins (12, 13) found that the higher intensity induced mutations in *Drosophila* with a frequency just twice as great as that for the lower intensity (13 lethal mutations in 2500 cultures as against 9 in 3481). Radiations in a carnotite mine equivalent to a known radium test produced 7 lethals in 2860 test cultures to 1 in 1308 controls (99, 100). Both experiments suggest the possibility of the influence of natural radiations in the production of spontaneous mutations.

Calculations based upon the induced results obtained with *Nicotiana* indicate that natural radiation may account for the known spontaneous rate of mutations (203). If the gene mutation rate in *Drosophila* is considered, natural radiation can account for only 1/1000 of the spontaneous rate (182), nor is there sufficient radioactive substance in the organisms or food to account for the rate. Calculations of the ions needed for the production of one lethal mutation in the series studied by Efromson also indicate that natural radiation is not sufficient to account for the rate in *Drosophila*. Due to the equal frequency of translocations and genes for a given dosage, Muller and Altenburg (179) concluded that the natural cause of mutations probably differs from x-rays in that the former produces more gene as compared to chromosomal mutations than do x-rays.

Agents active in production of mutations

The secondary or beta radiation was suggested by Muller (170) as the effective

agent in the production of mutations. Due to the close correlation of the ionization and the mutation-rate curves when superimposed, and since the beta particles do cause the ionization, Hanson and his coworkers (97, 105, 107) believe they have distinctly shown the beta particles to be the active agents in inducing mutations. In this they are supported by Timofeeff-Ressovsky (190); and Stadler (162) found that mutations may be produced by the beta rays of radiothorium and by cathode rays.

How agents produce mutations

Mutations are results of the direct action of x-rays. It is the position in the path of the rays rather than chemical composition that determines whether a gene mutates (170). This is shown by the fact that only one of a pair of allelomorphs is altered (170, 232), by the fractional effect from the treatment of sperm (170), by the independence of the degrees of change and dosage (170, 232), and by the direct proportion of mutations to dosage (173, 232). Muller (173) has found that transverse induction does not occur. Results offer no evidence of a delayed effect of x-radiation either in the subsequent generations (167), or in somatic tissues (173). If the directly induced lethal mutations in *Drosophila* are eliminated by proper matings, subsequent matings produce no "delayed" lethal mutations (87, 288, 290).

In the production of fragmentation, x-rays cause a degree of instability in chromosomes that is expressed only when the chromosomes come under the influence of energized cytoplasm (68). Although gene mutations seem to be due to immediate action, fragmentation apparently is due to a "post action" in the form of a durable chemical change in the plasm or chromosomes (128), and fragmentation is not due

to a general condition within a cell, but to local combinations of conditions near the place of breakage. Patterson (231) concluded that part of the effect of irradiation on elimination of a chromosome may be indirect.

It may be that the x-rays do not induce mutations, but merely reveal a pre-existing latent state (46) or that they exert selective action upon the normal type (190, 191). To this Muller (176) does not agree. The mutational effect of x-rays upon mature sperm of *Drosophila* is permanent during the life of the sperm (108); and Muller (167, 168) believes that the death rate of mutated sperm is no greater than that of the unaffected. Harris found no correlation between the production of mutations in sperm and their viability.

About half of the induced mutants prove to be sterile. Muller (168) observed that with most mutants the germinal does not correspond to somatic tissue, i.e., the mutants do not breed true. Hanson and Winkleman investigated 204 visible mutations induced in *Drosophila* with radium; of these, 43 were germinal; 80 did not breed true; 81 were sterile.

Muller (173) believes that induced mutations for the most part are not a result of the destructive action (losses) of the x-rays. Those mutations induced are in part similar to the spontaneous ones; the proportion of lethals to visibles, or of dominants to recessives, is similar to that in the spontaneous rate (168, 173). The genes that mutate more frequently spontaneously, also do with x-ray treatment, and they are scattered along the chromosome in the same way (168, 108, 232). That known chromosome abnormalities and gene mutations are not one and the same thing is shown by the partial separation of the two conditions with sex (232).

All mutations are losses according to

Serebrovsky (243, 245), and Dubinin (59). According to Stadler the possibility is not excluded that the induced recessive mutations are merely absences of dominant genes, although the appearance and behavior of induced mutations are the same as the spontaneous ones. In barley, few if any dominant mutants are found (258, 262), and this suggests the possibility that special classes of mutations are induced. Deficiencies in plants are lethal to the gametophytes. In maize among the plants grown from treated embryos, only the defective plants have the new (dominant) characters; and these traits are not reproduced to later generations (262). Patterson and Muller (232) recognize that some mutations may be losses, and Patterson (227) found that x-rays do produce many definite deficiencies that in so far as they can be measured cover only a single known locus.

Some progressive, non-destructive mutations are produced by irradiation. Reverse mutations in *Drosophila* of scute and forked have been induced (170, 232) and have been shown not to be due to suppressors. Eight mutations of normal to forked and eight of forked to not-forked were induced with none in an equal number of controls (173, 232). In the latter case a mutation of a mutated not-forked to forked was reported, showing that the x-ray action is reversible. Somatic reverse mutations also occur; however, the rate is not as frequent as for the other direction (218, 283, 284). Timofeeff-Ressovsky also found reverse mutations for several loci on X and III of *Drosophila* (286, 287). Changes that breed true have occurred in cotton from recessive forked to normal leaf, and from virescent yellow to green (117, 118, 119). In sorghum the change from recessive virescent yellow to dominant green has occurred (Hor-

lacher, Karper and Quinby, reported for 201).

Difference in susceptibility

Different loci in *Drosophila* vary in the frequency of induction (168, 170, 227, 286, 287). Patterson (227) connects this variation in some loci with the influence of deletions and viability genes. The frequency of deficiencies (loss of dominant genes) in maize varies for the different endosperm and plant genes tested (67, 261). Not only do different genes show a different mutation rate, but the rate varies for the same gene in different stocks (260). Timofeeff-Ressovsky (291) found in the induction of white and its allelomorphs that the Russian *Drosophila melanogaster* is more stable than the American. Whiting and Bostian (299) found different stocks of *Habrobracon* to vary in the production of "Shot" wing, as did Stubbe (275) in the production of variations in *Antirrhinum*, and Brittingham (27) in *Oenothera*.

The condition of polyploidy causes a variation in the frequency of response to irradiation. Oats and wheat with a basic chromosome number of 7 have a mutation rate equal to that of barley, but the frequency decreases with the increase in chromosome number (257, 258, 262). The lability of germ plasm after treatment is indicative of the evolutionary status of a species of *Nicotiana*, the species with the greater number of chromosomes having a greater variation of responses (70, 73, 74, 77).

Glass found in *Drosophila* that the regions of the autosomes nearer the spindle fiber are more likely to be fragmented by irradiation. Oliver (200) also reported a greater susceptibility of the right end of the X-chromosome, although this may be explained as due to the large bulk of inert material in this region.

Evidence as to composition and behavior of genes

Apparently a difference between the behavior of a gene in heterozygous and homozygous condition has been observed. When heterozygous agouti mice were subjected to x-ray, color was replaced by white; in homozygous agouti, by areas darker than the original. It is believed by Hance (91) that the heterozygous determiner is weaker and destroyed; the homozygous, stimulated to greater production.

In the analysis of the composition of the gene, evidence points to the fact that there are no gene elements. Mosaic tissue that sometimes occurs is not distributed in patch-work order; no "after effect" of irradiation is known; and most mutations are stable (167, 168, 170). At time of treatment, however, genes are compounded in the sense that only a part of a gene mutates. This is seen in the fractional effects induced. Fractionals are explained as due to the precociously doubled genes in the sperm, with only one daughter-gene responding to the treatment (167, 168, 170). Patterson (129, 231) found that mosaics from fragmentations do not appear after irradiation of female germ cells, although aberrant females do. He concludes from this and other results that the gametic chromosomes are not split in the eggs at the time of treatment, and that in the sperm the split has not always occurred.

Evidences of essential (viability) genes (24, 228) and support of the position-effect hypothesis discovered by Sturtevant in *Drosophila* have appeared in irradiation experiments (54, 58, 247).

Gowen and Gay (80, 82) used measured ionization and the mutations induced to determine the gene number and size in *Drosophila*. They found from calcula-

tions that there are at least 14,380 genes, each at least 1×10^{-18} cm³ in size.

VII. USES OF IRRADIATION IN OTHER GENETIC PROBLEMS

Mechanism of crossing over, synapsis, and reduction

Induced exceptions have been used to substantiate evidence that crossing over occurs in the four-strand stage, and that assortment is determined at the spindle fiber end of X (7, 9). In the latter report, Anderson drew the conclusion that whatever decreases the intimacy of synapsis, especially near the right end of X, causes a decrease in crossing over and an increase in the amount of secondary non-disjunction. Dobzhansky's results (53) corroborate this conclusion.

The results found with translocations in *Drosophila* suggest that the point of spindle fiber attachment of III plays an important part in the distribution of crossing over (49), although crossing over need not begin first at the spindle fiber (66). Homologous rearrangements indicate a regional differentiation in crossing over. With the ruby-lozenge region of the X-chromosome moved nearer the spindle fiber end, crossing over occurs in that region with a frequency of one-third its previous value (195). Similar results with other alterations have been reported by Offerman and Muller (196). Beadle (18) found with a homozygous translocation that the spindle fiber interferes with crossing over in its immediate neighborhood.

In an investigation of reduction in translocation III-II, the point of fiber attachment seemed to have the greater weight in deciding the direction of migration, since no non-disjunction involving fiber-attachments occurred. However, with a large fragment attached to IV, non-disjunction of IV occurred more often due,

apparently, to its small size as compared to the conjoined fragment (175). Investigations of several translocations indicate that one factor determining the disjunction of involved sections is the relative length of these sections; the spindle fiber is a secondary factor (52, 53, 57, 278).

Synapsis and crossing over are due to an attraction between genes (homologous parts) rather than to the chromosomes as a whole (51, 53, 57, 170). Homologous parts tend to synapse even when attached to unlike parts that bear the spindle fibers (173, 183). This is observed especially in reciprocal translocations of *Drosophila*, in which the two large V-chromosomes have exchanged arms. Somatic pairing is never normal, but is characteristic for the attraction of like parts (57, 202, 278, 294). In maize, pairing was reported as that expected on attraction (152), although recent work seems to determine that at certain stages this is not true (153).

Since chromosomes are tenacious, attractions pulling in different directions (translocations) or the conflict of attracting forces (inversions) limit crossing over (51, 53). Beadle and Emerson have used combinations of heterozygous translocations, and from the results concluded that the reduction in crossing over near the point of fragmentation requires another factor than counter attraction as an explanation. Somatic pairing in *Drosophila* corresponds to the observed crossing over and corroborates the interpretation of Dobzhansky (51). If no crossing over occurs, the tendency is for the involved pair of chromosomes to show no attraction; if crossing over occurs only in one arm, only one arm pairs with its mate in the homologous chromosome (202, 294). Genetic investigations of the influence of translocations on crossing over have been made with homozygous and heterozygous

aberrations. In all the intervals studied by Dobzhansky (47) in homozygous translocations, crossover values were but slightly, if at all, different from the standard values. Later, Beadle (18) did find some variation in the regions near the fiber locus. In the heterozygous form, crossing over occurs between the fragment and its normal homologue, but with a reduced frequency (170). In general, crossing over is decreased in the whole limb that is fragmented and increased in the other limb (53 and earlier). If the break occurs near the fiber locus, crossing over in the fragment may or may not be affected (51). Van Atta (294) and Glass found that such a break did not affect crossing over in either arm. The presence of a duplication of II (236) and of X (51) was found to decrease crossing over in the regions near the respective point of breakage even though otherwise a normal chromosomal configuration was present.

Mapping of genes upon chromosomes

The linear sequence of the genes in *Drosophila* as theoretically mapped is shown by the results with fragmentations to be correct. Genes involved in a translocation or a deletion constitute a coherent section of genes that corresponds to the fragment. However, the linkage maps do not represent the spacial relationship of the genes on the chromosomes. Crowded map regions are found to represent greater lengths cytologically; sparse regions on the maps are not as long physically in II and III (48, 49, 50, 51, 178, 183) or in X (55, 184, 212, 213, 214, 215). All the known genes in X except bb are found to be in about the left half of the chromosome, the right half being homologous to the Y-chromosome.

Mapping of chromosomes is made more definite by the use of irradiation. In the small IV of *Drosophila* the locus of *cy* has

been separated from *bt* by a fragmentation (24). The use of an induced translocation determined the pair of chromosomes in *Apoteitix* responsible for the 13 factors for the dominant elementary color patterns (186, 187, 237). By a combination of the cytology and genetics of aberrations it has been possible to determine the regional location and the order of genes in maize linkage groups (152, 262).

Sex determination in Drosophila

Evidence that might offer some explanation of sex determination has been watched for in translocation and fragmentation work. That the left half of X is probably not sex determining was concluded by Muller and Altenburg (178). Certain duplications of X did not prevent males from breeding, and these regions were considered to be free of sex determiners (214). Suggestions of the use of duplications and translocations were referred to by Muller (173, 185). Evidence has also been sought in aberrant and gynandromorphic flies. Results by Patterson with special cultures indicate that a region near garnet may include a primary sex-factor, gene or genes (221, 223, 225); but in an investigation using intersexes, duplications of X were found by Dobzhansky and Schultz (56) to cause a shift towards femaleness, the longer the piece the greater the shift.

Variegated characters

Every known case of mottled eyes in *Drosophila* involves the locus of white and some kind of fragmentation with reattachment (24, 170, 173, 174, 226). Muller (173) does not believe that the variegated condition can always be explained as a loss. However, in one case, the fragment of X is attached to IV and

apparently lost during somatogenesis. This mottling is interpreted by Patterson and Painter as due to an unstable translocation (226, 233). Gowen and Gay (81, 83) found evidence to support the conclusion that the Y-chromosome plays a part in mottling, as does also temperature (84).

The "eversporting" eyes are dominant and variegated, and continually mutate (170, 173, 174, 295, 296). All induced dominant eye colors are not variegated (198, 293, 294); but all observed variegated conditions are in some way connected with fragmentation of an autosome. Van Atta (293, 294) found the tested variegated mutants to be allelomorphs, located in the right region of II. Glass located three groups of allelomorphic genes for variegation, and found that variegation does not depend solely upon the connected fragmentation. Reversions of the visible mutation back to the normal type occur, but the translocations are retained. Morgan, Bridges, and Schultz (163) reported one mosaic to be allelomorphic both to light and to brown.

Maize endosperm mosaics are due in part if not in all cases, to the loss of a part of a chromosome (258), and within these areas are spots that show recovery or return to the dominant type. This recovery occurs in control as well as in treated material, and in spots with no internal connections (259, 261).

Oenothera problems

The tendency for the induced translocations in some cases to form the old, parent combinations, the occurrence of mutual translocations, the decrease in the frequency of crossing over in heterozygous translocations, and the presence of a lethal condition in most homozygous translocations are conditions that offer aid in the

explanation of the known conditions in *Oenothera* (57, 175, 278). Judging from somatic pairing when chromosomes of *Drosophila* have exchanged whole arms, rings probably are formed during maturation (57).

Variations in the dose of definite genes and of chromatin

One dose of purple (deficiency) produced no exaggerated effect (162). Muller found that an increased dosage of genes caused an increased phenotypic effect. If recessives are added, the effect approaches, or is greater than normal. These genes produce an effect like, but less than normal genes. On the other hand, bar and other dominants produce an effect different from that of normal (181). Dobzhansky and Sturtevant (58) found that the addition of the normal allelomorph in fragments does not suppress the action of a recessive gene as strongly as does the normal allelomorph in triploid condition. A similar condition was reported by Sivertzev-Dobzhansky and Dobzhansky. The explanation may be genetic balance or it may be position effect. A somatic cell in a *Drosophila* male that loses a piece of the X probably dies.

This conclusion is based upon observed scars of the eye (218) and on the lack of gynandromorphic parts having only the lethal ClB combination (223). Chromatin added as a duplication generally is expressed by phenotypic variations, although not in all cases.

Other uses

Irradiation has been used to study the rôle and significance of quantitative chromosomal changes which are reflected in alteration of specific plant characters and to get self-perpetuating new lines in *Nicotiana*, differing from the untreated parents in external morphology (74, 75). Induced mutations have made the analysis of inversions less difficult (185), and an induced translocation has been used by Stern (271, 272) to aid in the cytological proof of crossing over in *Drosophila*. Variations in abundance occur with the proper irradiation of an organism. No method has as yet been reported by which the induction of the genetic effects may be controlled. It is possible only to irradiate and to accept the results produced, but each experiment presents new and interesting conditions.

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ON THE DYNAMICS OF POPULATIONS OF VERTEBRATES

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I

THIS paper is a summary of a more extensive work on the biology of reproduction of higher vertebrates. The latter work, which is forthcoming, is devoted to the comparative study of the growth of populations of the higher vertebrates. The statistics of the game in hunting grounds are practically the only source of information available about the dynamics of populations of birds and mammals. A clear concept of the biology of the forms studied is of course necessary for analyzing these statistical data, but in view of the briefness of this summary, attention is chiefly concentrated on the analysis of the curves showing the growth of the animal population. The description of the biology of the animals and examples illustrating the character of a very important phenomenon—the recurrent plagues among vertebrates—are also reduced to a minimum.

The analysis of the statistical data required the adoption of such a method of investigation as should give the possibility of estimating the trustworthiness of the figures and at the same time of ascertaining the relative importance of the single factors worked out in the course of evolution and determining the rate of growth of the number of animals of different species. I calculated theoretically the rate of increase in the numbers of animals on the basis of our knowledge of the fertility of animals as it is available in the literature, though this knowledge may

not be very exact. I then compared the figures obtained theoretically with the figures representing the dynamics of animal population as observed in life.

Since the logarithms of terms of a geometrical progression form an arithmetical progression, I plotted the logarithms of the yearly registrations. In this way I could judge, by the closeness of fit of the points to a straight line, the exact measure of correspondence between the theoretical results and the reproduction of animals in real life. This method enabled me to show that the growth of the numbers of vertebrates in life actually follows the exponential curve, determined, for different species, by the species constants of reproduction (*Vide infra*) corrected for a definite value of the death-rate among the adults and among the young.

A preliminary communication about some questions studied here more minutely has been already published (S. A. Severtzoff, 1930). Endeavoring to determine the curve of growth of animal populations, I followed the path traced by ichthyologists studying in detail the age groups of different fish populations, whereas the majority of students of the growth of human population, as well as of the population of invertebrates easily reproducing themselves under conditions of laboratory life (*Drosophila melanogaster* and some other forms), are satisfied with the study of the growth of the population as a whole. It was found in many cases that the growth-rate of the population could be adequately

represented by the so-called Verhulst-Pearl logistic function,

$$y = \frac{k}{1 + e^{bx}}$$

The logistic curve has the form of an S, showing that the absolute growth-rate increases slowly in the beginning of the period of growth, that it then accelerates, and that, finally, after a certain critical point of the density has been reached, it gradually decreases.

Pearl (1920-1923) showed that the logistic curve adequately describes the growth of human populations. His experiments with *Drosophila* have also shown that the increase in numbers in conditions of laboratory life attains the greatest rapidity in the case of an optimum density; in the case of a smaller or a greater density, the growth is smaller. We cannot see in the coefficients of Pearl's equation quantities having a biological significance. It is plain at the same time that there is nothing in common between different biological phenomena underlying the processes of reproduction of different forms, though they may be represented by one and the same curve. Chapman cultivated *Tribolium confusum* in a certain amount of flour. This flour was periodically renewed so that the quantity of flour might be sufficient for the population, but, while the number of worms increased, the rate of growth of the colony was delayed, because, together with the flour, the insects devoured the eggs laid in it.

A colony of *Drosophila* was bred in bottles of limited volume and in this case, as well as in the case just mentioned, the rate of reproduction decreased, while the population increased. The causes of the two processes being different, it is perfectly plain that both these cases have nothing in common with the growth of human population. The complicated so-

cial relations in conditions of class strife, the coefficients of death- and of birth-rates in different classes, the immigration and the emigration of the population and the relative development of the productive forces in different countries do not allow one to compare the growth rate of human population with the reproduction of animals without a special analysis of both. Thus we have to admit that, though the logistic function gives us the possibility of representing the growth of the population from its external aspect, it does not assist us in the understanding of the biological significance of the phenomenon.

The large investigation of Fisher appeared in 1930. Fisher put forward an index of growth which he called: "the Malthusian parameter." He examined the fertility and the mortality rate of different age groups and suggested an equation which allows one not only to calculate the growth-rate on the basis of given birth- and death-rates, but also to foresee its dynamics in future. Unluckily the method of Fisher cannot be applied to animals, as he proceeds in his calculations from the mortality tables used by life insurance companies and from birth tables derived in the same way. These kinds of statistical data are available for human populations, but they do not exist for animals.

The same year 1930 saw the publication of the work of Cholodowskij. The author considers only the mathematical aspect of the problems; he gives equations for the calculation of the number of animals, when the following data are known; the number of pairs of ancestors, the age of sexual maturity, the length of the period between two consecutive parturitions of the female, etc., i.e., the inherited characters, which we call the "constants of reproduction of the species;" he does not take into consideration the mortality of

the animals, which is reducing the potential growth of the population.

Pearl's (1926) so-called "vital index" is evidently largely recognized by demographers studying the growth of human population. This index determines the growth of the population of a given country by the ratio of the births (B) multiplied by 100 to the deaths (D). When the figure exceeds one hundred it means that the population is increasing, when it falls short of one hundred it means that it is decreasing. The difference between the fertility of man in different countries and the fertility of different species of vertebrates is so great that it is not possible to apply methods worked out for the human population, when we have to compare the fertility of different species, and in order to be able to make such a comparison I had to work out a special index of fertility of species.

I dealt in my paper of 1930 with the following questions: what are the factors determining the growth rate of the population of different species; what is the curve formed by the growth of the population, and what are the factors delaying or interrupting the growth? The index of species fertility which I suggested— q —allowed one to characterize, in a first approximation, the relative fertility of different species in so far as this fertility depends on the inherited characters of the individual.

In life we always have to do with the reproduction of a certain number of individuals forming a herd, this reproduction going on for several years. In the case of the majority of vertebrates the parents are still living when their young have attained the age of maturity and are breeding in their turn. Thus the herd is composed of several age groups. Every year a certain number of the individuals of each group perish and the diminution of each age

group is compensated, as a rule with some surplus, by individuals of the next younger age group. Thus the age composition and the curve of increase in numbers are determined by the birth- and death-rates of the age groups composing the population.

We shall begin by considering the rate of reproduction of vertebrates (without first taking into account the mortality of animals) and we shall try to compare the potential fertility of different species. (My conception of the potential of fertility nearly approaches Chapman's conception of the biotic potential, which he proposed some time ago, but which was unknown to me till the year 1933. However I prefer to retain the term "the potential of the fertility of species" because as it seems to me, it expresses my idea more clearly and more adequately.) Each herd reproduces itself according to the rate of individual development and the fertility of the individuals forming the herd, and we have to trace how far the characters of the individual are manifested in the fertility of the herd.

The potential rate of increase of the herd depends upon the inherited characters of the individuals of each species, which may be called constants of reproduction of the species; these constants are just as characteristic of the species as its morphological characters. Such constants are the following, calculated by the method of variational statistics: the number of the young produced every year by one pair (r); the age of the first parturition, i.e., the age of sexual maturity plus (for mammals) the length of the period of pregnancy (j); the period between two consecutive parturitions of the female (p). The relative number of the sexually mature males and females in the herd and the percentage of barren females have, so it seems, only a secondary importance and the deviation from equality of the numbers of males and females, in the case of vertebrates, is

hardly determined by heredity. A theoretical curve of the increase of the herd can be drawn for each species when the above named figures are known. Several curves

deduced by the female every year (r), the increase of the herd being the more rapid, the greater the value of r (Curves j_3r_3 , j_3r_4 , j_3r_5). When r is constant the repro-

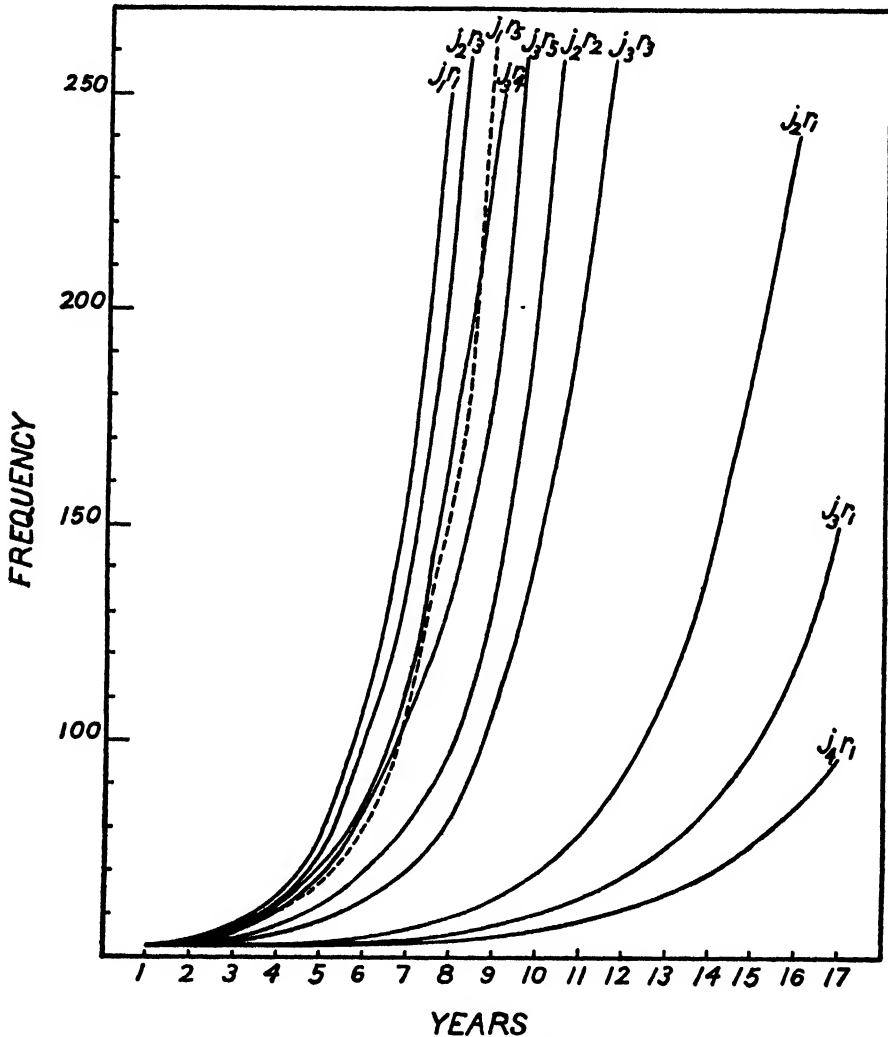


FIG. 1. THEORETICAL CURVES OF THE INCREASE OF THE HERD, FOR DIFFERENT VALUES OF THE SPECIES CONSTANTS
 j = age at first parturition, r = number of the young produced by the female per year. The curves show that the rate of increase is accelerated with increasing r and reduced with increasing j .

calculated from the formula of Choldowskij (1930) are given in figure 1. Examining them we see that the rate of growth of the herd is determined in the first place by the number of young pro-

duction of the species is slower, the greater the value of j (j being > 1 year). The rate of growth is still slower when the females do not bear every year, but at longer intervals of time, for instance once

in two or three years. The retardation of the growth of the herd, when p has a value greater than one year, is proportional to $\sqrt[p]{r}$.

Examining the curves of figure 1, we find that the difference between the course of the curves r_{1j_1} and r_{1j_2} is considerably greater than the difference between the course of the curves r_{1j_2} and r_{1j_3} , and that this difference is entirely due to the value of j in this interval. The comparison of the curves of potential fertility of the herd brings us to the conclusion that the different species of vertebrates can be arranged according to their fertility in a very regular sequence, not only the number of young, but also other constants of reproduction of the species being of importance.

The growth rate of the herds of two different species may be the same, although the number of young borne by the females of these species be different, if the constants of reproduction j and p have corresponding values. Now we can express the index of the species fertility (q) by the equation

$$q = \left(1 + \frac{r}{(Fj)}\right)^{\frac{1}{p}}.$$

where $Fj < j$. The exact function of j (Fj) was not ascertained by us, but the examination of the curves shows that $Fj < j$. Still we may use j , as the changes in Fj correspond to the changes in j . Introducing into this expression the values of the figures for the constants of each species we can characterize the fertility of one species in relation to another by one figure.

We have to note here that from the point of view of the biology of reproduction of the herd the constants j and p are not only temporary categories, as they appear to be at first sight, but, together with the percentage of the barren females and the relative number of the individuals of different

sexes, they represent the coefficients determining the number of those individuals in the herd that are not bearing every year. The individuals not bringing forth any issue in the given year, either because they have not yet attained the age of sexual maturity or because they have bred the year before, still go on living in the herd; together with the others they use up the food supply of their habitat (*Wohnraum* of German authors) without taking part in the reproduction of the herd. The yearly reproduction of the herd evidently depends upon the number of the bearing females alone and this number may be greater or smaller according to the value of j and p .

I showed in my work of 1930 that the duration of life of the individuals, as characteristic for the species, stands in an inverse proportion to the logarithm of the index of the species fertility q . The fertility of the species decreases with increasing duration of life not only at the expense of the reduction in the numbers of the young produced by the female, but also in consequence of the rise of the values of j and p , that is, in consequence of the reduction in the numbers of bearing females in the herd.

However, we cannot confine ourselves to the comparison of the potential fertility of different species, the growth of the herd of any species in nature being reduced by the mortality of the individuals in their struggle for life. In accordance with A. N. Severtzoff (1917) we may distinguish the mortality of the young individuals, sexually immature, and the mortality of the adult animals, the age of sexual maturity representing the limit after which the young animals generally attain the full development of the characters distinctive of the species. The reproduction of the animals is subject to a yearly cycle and generally falls in the spring and summer period of the year. According to the

length of the period of gestation and of the development of the egg, some species bear in the summer of the same year, when they have attained sexual maturity, while other species, with longer periods of gestation, having attained sexual maturity in autumn, bring forth a brood in the summer of the following year—e.g., the reindeer, the horse and other species, where the period of gestation lasts 9 to 11 and more months. Therefore, examining the growth-rate of the herd I think it preferable to take into consideration not the age of attained sexual maturity, but the age of the first parturition of the female, i.e., the age of attained sexual maturity plus the length of the period of pregnancy. This is in so far preferable as it is exactly the moment of the birth of the individual, which is of importance for the course of the geometrical progression of reproduction. Thus we shall distinguish the mortality of the young animals for the period j from the mortality of the adults and designate it by the letter m .

We can distinguish in the total number of any species three groups of different ages: (1) the sexually immature individuals, born in the given year or earlier; (2) the adult and breeding individuals forming the main group of the species; and (3) the old individuals which have outlived the period of activity of the sexual glands and are unfit for reproduction. If we examine only the growth of the adult group, which is increasing at the expense of the young group, having outgrown the period of mortality in the early age, the coefficient of mortality introduced by us will be equivalent to the decrease in the numbers of the new-born young. Therefore the curves of Figure 1 may be considered as showing the increase in the numbers of adult individuals out of whose brood the number $r_1 = r - m$ attain the age of first parturition (where $r > m$).

If the yearly fluctuations of the mortality of the young are not considerable, they evidently cannot change the character of the curve of the potential growth of the herd and transform the exponential curve into a logistic one. Such a change might take place only in the case where the increase in the mortality rate among sexually immature young or among the adults was progressing according to the growth of the population or in the case of a corresponding increase of the birth rate. Further investigations must show whether such phenomena take place in the life of vertebrates.

We possess hardly any figures characterizing the mortality of the adult individuals, but we know that it is subject to violent fluctuations and that there are years when it acquires the character of a mass plague. A series of observations leads to the conclusion that the periodic mass plagues are not an accidental, but a regularly recurring phenomenon dependent upon periodic changes in the external environment of the animal. Different species react differently to the same changes in their environment, according to peculiar characters of their constitution and their biology, as they have been worked out in the course of evolution. Fur-trade statistics and direct observations of the number of different species in nature have shown that there are years when the number of animals abruptly decreases and that it then gradually rises to the former level (Turkin, 1900; Elton, 1927). These declines are not brought about by man, interfering with the conditions of life of the animals, but by natural causes.

We have to look for the causes of the plagues in the first place to violent deviations from the optimum of the climatic conditions, acting sometimes directly, sometimes indirectly. The climatic elements vary about a certain mean, extreme

deviations occurring more rarely than slight ones. An extraordinarily deep snow in winter, covering the green herbage, results in the starvation and death of herbivorous animals. Snow-storms, glazed frost, inundations, droughts, prairie- and forest-fires, dearth of pasturage increase the mortality directly or indirectly and bring about mass plagues.

It is not always absolute deviations from the optimum of one of the climatic elements that are of greatest moment for animals, but often certain combinations of these elements, which can hardly be detected by meteorological stations of the ordinary kind; thus a plague may be caused in winter time by a comparatively slight fall of temperature, after a thawing of the snow and a rain, when the ground is covered by a hard ice-crust which prevents the animals from grazing. A plague among the herbivores naturally deprives the carnivorous animals of food and they die of starvation. Different species react differently to changes of climate and other factors in their environment, and a depression which means death for less resistant animals can be borne comparatively well by more resistant ones.

Another essential category of causes bringing about plagues among animals is epidemic diseases. A pest epizootic in the nineties caused the death of 90 per cent of the ungulates in Africa. We know of anthrax epizootics among reindeer, of coccidiosis and helminth infections among rodents and ungulates. In so far as infectious diseases resulting in plagues are brought about for each species by specific bacteria, protozoa, or helminth parasites, we have to admit that the agent of the disease always exists in the host population and that in certain conditions, increasing the possibility of infection of healthy individuals or reducing the resistance of the host in relation to the parasite, the disease

spreads widely and can attain the character of an epidemic.

Direct observations have shown that a rainy summer with its many pools inhabited by *Limnaea stagnalis*, the intermediate host of *Fasciola hepatica*, contributes to the infection of hares, reindeer, sheep and some other herbivorous animals by the larvae of this parasite. When the same climatic conditions have caused an under-feeding of the game and thus reduced its resistance and its capacity to withstand the parasite, a violent infection will bring about an epidemic plague. When the number of animals of any species has reached its peak during a favorable period of the summer half-year, the food being sufficient and more animals being able to live on the same space, or during a period of several consecutive favorable years and when after this the conditions change for the worse, the numbers of animals prove to be so great that the conditions of life for each individual also change for the worse. The individuals cannot resist the disease and the density of the population itself contributes to the infection.

For the majority of rodents we are able to establish a regular periodicity of epidemic plagues from infectious disease, following on a mass reproduction of animals. The same periodicity has been established by Elton (1927) for predators preying upon these species. However, at least according to fur-trade statistics, such a regular periodicity could not be traced in relation to ungulates and less fertile rodents (*Castor fiber*). Nevertheless what has been said above about recurrent violent deviations of climatic factors from the average and about epidemic diseases forces us to admit that all species are, from time to time, subject to plagues, but that the frequency of these plagues must be different according to differences in the constitution and in the biology of the species.

There is one more point of great moment, which has to be considered. Plate (1913) is right in pointing out that plagues caused by abiotic factors are not connected with the density of the population; a sparse population may perish from inundation, glazed frost, or dearth, just the same as a dense one. Therefore, insisting upon the fact that the resistance of different species is different in regard to the same changes in their environment, we think that within the limits of the same species extreme deviations from the optimum exceed the endurance of individuals to such an extent that their individual characteristics lose their importance and survival is subordinate to the law of great numbers. Therefore the greater the number of individuals forming the population of a locality before the breaking out of a plague caused by abiotic factors, the greater will be the number of individuals surviving the plague, and the more certain the restoration of the level needed for enabling the species to survive the next coming depression. If any of the species does not succeed in restoring its level a still smaller number of individuals will survive the next coming depression and the species will die out.

We have laid stress on abiotic factors of the plagues because the conditions for the possibility of surviving depressions caused by abiotic factors require the highest possible population. A dense population is a factor favorable for the spreading of epidemic diseases which also destroy the population according to the law of great numbers, although this density is not the only cause of diseases. We hold that the fertility of the species must correspond to the statistical recurrence of fluctuations in abiotic factors dangerous for the species, but in cases when the next depression is late in coming and the population has reached its highest density, there appear

conditions favorable for the development of epidemic diseases. This fact must lend to the periodicity of epidemic diseases a greater regularity.

Direct observations on the periodicity of plagues show that some species are subject to them more often than others. From what has been said above about the potential fertility of animals and about some species being so much less fertile than others, it follows that if the frequency of the plagues caused by epizootics or by extreme deviations of climatic factors from the optimum were the same for fertile species as for infertile ones, the less fertile species would not have time enough during the favorable period for the restoration of their numbers reduced by the plague; therefore in a comparatively short time these species would disappear from the face of the earth. This shows the utter impossibility of admitting a simple periodicity in the mass reproduction of different species, connecting it with the periodicity of climatic fluctuations, resulting from the 11 year cycle of sunspots, as is done by Elton (1927).

As has been observed for many species, the coefficients of the periodic reproduction and of the dying off of the population must be specific for each species and must correspond to the potential fertility and to the mortality rate of that species between two plagues. We can gain knowledge about the rate of growth of the herd in the periods between two plagues only by studying the actual increase of the animal population in nature. Holding it necessary that specific investigations should be organized chiefly in national parks, we think nevertheless that, although the data already accumulated have been gathered with a different purpose and although they are not always sufficiently precise and complete, it is still possible to use them in order to make an attempt to

approach the question of the dynamics of a herd of vertebrates.

II

We are in possession of some statistical data left from the former imperial hunt in Gatchino near Leningrad, concerning the number of five species of game of the grouse family (Tetraonidae) and also the number of roes (*Capreolus capreolus*), these data recording the results of the hunting and of the struggle with predators for a period of 25 years—from 1886 to 1909. A report on these statistical data was presented by the chief administrator of the hunt, Dietz, at the Second Congress of Hunters in 1909 and they were published in the *Proceedings* of the Congress, but unluckily without the explanatory notes. The gap has to be filled up by desultory indications of Dietz, made at the Congress, and by some material drawn from the literature on the subject.

The imperial hunting grounds extended over more than 200,000 hectares and were carefully guarded against poaching, any unregistered shooting being thus excluded. The percentage of the game shot in the hunting grounds is very low. At the same time the curves representing the numbers of the birds of prey which were shot show a permanent increase due to the growth of the numbers of the game; thus we see that in the Gatchino hunting grounds the natural correlation between the predatory birds and mammals and their prey and also the standards of the reduction in the numbers of the game in its struggle for life were not seriously upset.

The use of the statistical data concerning the quantity of game in Gatchino presented a certain difficulty since the data included only the following points: the number of the young in each nest for each year, for all species taken together, and the total number of the young. I had there-

fore to calculate the number of the young for each species separately on the basis of the average number of the young in the nest, correcting the figure obtained for the fertility of each species. After summing up, for verification, the number of the young of each species, I compared the figures obtained with those given by Dietz and found the difference to be 1 to 2 per cent. Taking into account the degree of precision attainable by the registration, this difference may be considered unimportant. The number of breeders and the figure for the young being known for June and July of each of the 25 years I could calculate the yearly percentage of growth in the number of breeders, the percentage of survival and of the reduction in the numbers of the young for the winter period and, finally, Pearl's vital index; the number of the eggs laid by each female and consequently the number hatched not being given, I had to adopt for this number the number of the young in summer with the subtraction of the figure for the game shot. These calculations were made for the capercaillies (*Tetrao urogallus*), for the black grouse (*Lirurus tetrix*), the heathcock (*Tetrastes bonasia*), the ptarmigan (*Lagopus* sp.), the partridge (*Perdix cinerea*) and the pheasant (*Fasianus colchicus*). All these birds are non-migratory and very slightly nomadic. This gave me the certainty that the figures obtained showed the real mortality rate and not the result of migration from the territory. Tracing the fluctuations in the numbers of these birds during a period of 25 years I could note a series of peculiarities in the reproduction of each species, but I shall give here only the description of the growth rate of the herd of partridges, and in part of the capercaillies.

In Gatchino the partridge was the most numerous bird. It is a very fertile bird, laying from 15 to 24 eggs. The young

partridges build their nests in the spring of the first year of their life and both parents take care of the brood. The growth of the herd can be easily followed in Figure 2 and Table 1. The number of birds for the summer of each year is represented by a column, the black part corresponding to the number of breeders and the other part to the number of the young brood at the moment of the registration (about June or

determined by the number of birds surviving the winter. The percentage of the surviving young birds appears to be very constant; we determined it as the ratio between the number of the young of the preceding year and the increase of the adult birds of the following year, when the birds, having survived the winter, began to breed in their turn. From year to year the percentage of survival was 5 to

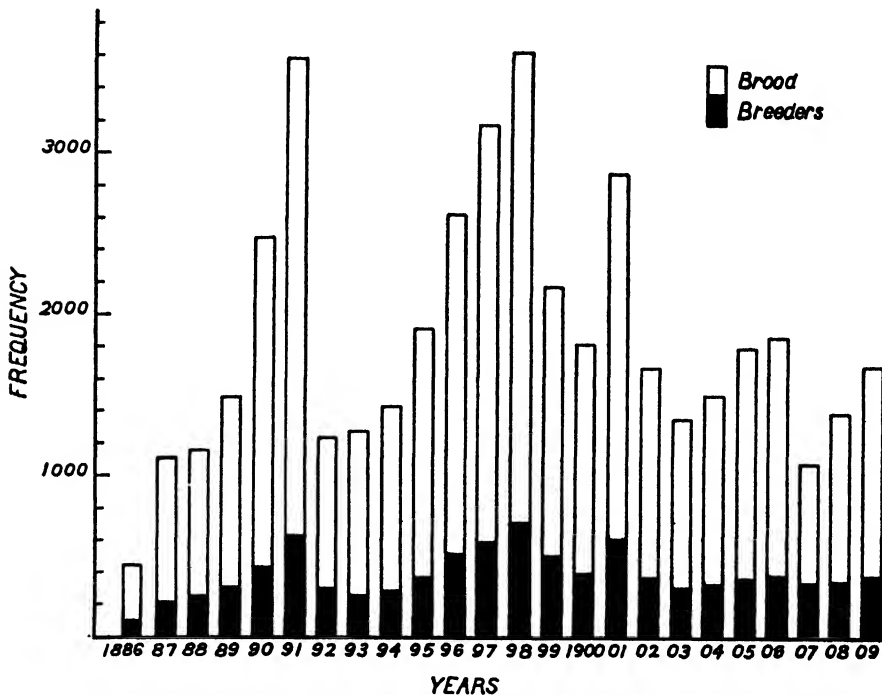


FIG. 2. DIAGRAM OF THE DYNAMICS OF THE HERD OF PARTRIDGES (*PERDRIX CINEREA*) IN GATCHINO FOR THE YEARS 1885-1909

Each column represents the number of birds in the summer of the corresponding year

July). The shooting of the partridges in Gatchino was not considerable; it amounted to only 6 per cent a year and could not affect sensibly the number of birds. We see that the number of partridges was subject to very great fluctuations. The young birds, registered one summer, passed in the spring of the next year into the group of breeders; thus the increase in the number of breeders was

6 per cent of the total number of the young bred during the summer minus the birds shot; this secured the increase of the breeders in favorable years to the amount of 28.4 per cent. The reduction in the numbers of the young brood during the winter was rather less as obviously there also perished a certain number of the old individuals. This latter number is unknown to us but in some measure it in-

creased the percentage of the reduction in the numbers of the young. The reduction in the number of the whole herd was 70 per cent on the average. The reduction in the numbers of the brood in winter, as

taken together, was considerably reduced. We can trace a perfectly regular increase in the number of the breeders during six years, then an abrupt decline during two years, the decline in the second year

TABLE 1
*Dynamics of the Herd of Partridge, *Perdrix Cinerea*, in Gatchino*

YEARS	NUMBER OF BREEDERS ♂ + ♀	NUMBER OF YOUNG FOR THE SUMMER	GAME SHOT IN PER CENT	MORTALITY IN THE HERD — GAME SHOT	SURVIVAL OF THE YOUNG FOR THE WINTER IN PER CENT	MORTALITY OF THE YOUNG FOR THE WINTER IN PER CENT	GROWTH AND REDUCTION OF BREEDERS IN PER CENT OF THE NUMBERS OF PRECEDING YEARS
1886	104	363	14.3	—	—	—	—
1887	226	903	1.4	40.0	39.2	60.9	+117.0
1888	258	896	1.2	75.2	3.1	97.0	+14.0
1889	314	1198	10.8	72.1	6.8	93.2	+22.0
1890	454	2043	3.8	68.1	12.0	88.0	+45.0
1891	646	2968	2.6	71.0	9.8	89.2	+43.0
1892	302	950	3.5	94.5	0.0	100.0	-53.0
1893	268	1010	5.8	76.0	0.0	100.0	-11.0
1894	314	1122	0.2	70.3	4.8	95.2	+17.0
1895	390	1534	5.8	72.5	6.8	93.2	+24.0
1896	540	2111	5.9	67.4	10.3	89.7	+38.0
1897	600	2604	6.4	72.7	3.1	96.9	+11.0
1898	714	2934	3.4	72.5	4.6	95.4	+19.0
1899	552	1698	11.9	96.8	0.00	100.0	-25.0
1900	422	1421	7.1	71.7	0.00	100.0	-19.0
1901	636	2286	7.3	60.0	1.62	98.4	+50.0
1902	380	1315	6.7	81.3	0.00	100.0	-40.0
1903	332	1031	3.1	75.5	0.00	100.0	-12.0
1904	348	1181	9.6	72.3	1.6	98.4	+5.0
1905	394	1424	—	67.0	4.3	95.7	+13.0
1906	410	1499	13.5	77.4	0.00	100.0	+4.0
1907	288	921	17.3	68.5	0.00	100.0	-30.0
1908	360	1048	3.6	40.2	9.5	90.5	+25.0
1909	390	1312	—	70.0	29.8	70.2	+8.0
Mean.....			6.3	71.8	6.45	97.2	

Mean growth in the numbers of breeders for the years of growth = 28.4%

Reduction in the numbers of breeders

(a) for the first years of the plague = 39.0%

(b) for the second years of the plague = 14.0%

calculated by me, was as much as 90 to 95 per cent for the years when an increase in the number of breeders could be observed. The examination of the diagram shows that there were years when the number of the whole herd, old and young individuals

being somewhat less than in the first; after this comes a second period of six years of regular growth in numbers and a new decline followed by a comparatively inconsiderable increase in numbers during three or four years, then again declines on a

smaller scale than the two first ones. It is evident that we have to do here with a periodic mass reduction in the number of birds, but no explanation of its causes is to be found in the records of the Gatchino hunt.

However, the knowledge of the biology of the partridge shows that these birds perish in large numbers during a severe winter and that besides they suffer from epidemic diseases and helminth infections. Unregistered shooting and lawless extermination of the game were excluded in the conditions of the Gatchino hunt, therefore we can admit only natural causes of the plague. Our attention was arrested by the fact that the reduction in the numbers of the herd went on for two or three consecutive years, (except, perhaps the year 1900) (Fig. 2). A plague caused by abiotic factors could last only through one winter but if the cause of the plague were disease or infection by parasites, the effect of these causes could last through periods exceeding one year's cycle, stopping only when the population had attained the sparseness necessary for preventing the parasites from attacking the healthy individuals too easily. A minute comparison of the fluctuations in the numbers of game with meteorological records of the chief geophysical observatory did not give any positive results.

Concerning the plague of 1900 I have some doubts, seeing that after the reduction in numbers of that year there was a very large percentage increase of the breeders. The old birds that had passed the age of breeding were evidently not registered; meanwhile it often happens that young birds perish in large numbers as a result of the spring frosts; while older ones safely survive them. We have thus come to the conclusion that the reduction in the numbers of the breeders in the year 1900 was only an apparent one.

Pearl's vital index of the partridge is very characteristic for this fertile bird; it proved to be $100 \frac{B}{D} = 107$ on the average for 23 years. Leaving out the first and the last year we have $100 \frac{B}{D} = 101.2$ or an almost total absence of any growth, although in the intermediate years the increase of the number of birds was very great (from 1000 individuals to 3600).

We can also note a very interesting coincidence between the five or six year periodicity in the increase of the numbers of the partridges with the duration of life of this bird, which, according to Mitchell (1911) attains seven years.

From the regular disposition of the logarithmic points showing the yearly number of the breeders, we can see how regular was the rate of reproduction of the partridges. On Figure 3 the years are marked along the abscissa, the logarithms of the numbers of the yearly registration along the ordinate. The regular disposition of the points shows that the growth of the population followed the exponential curve determined by the species constants of the partridge, corrected for the mortality rate for the first year of life, which for the partridge coincides with the age of the first production of young by the female. The mortality of the young was as high as 90 per cent. Examining the disposition of the logarithmic points on Figure 3 we see that the points of the ascending as well as those of the descending range are disposed with more or less regularity on straight lines. This alignment shows that the reduction in the numbers of birds also regularly followed a negative exponential curve. What is the reason for that reduction? If the increase of the mortality rate had been caused by climatic factors, for instance by a very severe and snowy winter, we could expect to find an abrupt

decline in the numbers of birds during one winter but, this cause ceasing to act the next spring, the number of birds ought to have again increased. The disposition of the points indicates a cause acting for more than one year. Volterra (1928) points out that the decline in the numbers of herbivorous species as a result of encounters with predatory species follows a descending exponential curve. He includes under predators the agents of diseases. The simplest explanation of the periodic plagues recurring among the partridges is the helminth invasion. The

proved to be very near the figures which we had obtained for the partridges; periodic plagues were observed for other birds as well with the exception of the capercaillies (*Tetrao urogallus*). During the whole period of 25 years there was not a single considerable decline in the numbers of the capercaillies, but the growth of the herd of this species proved to be much slower than the increase in the numbers of partridges. Without entering into a closer analysis of the increase in the numbers of capercaillies, suffice it to say, that the duration of life of this bird is consider-

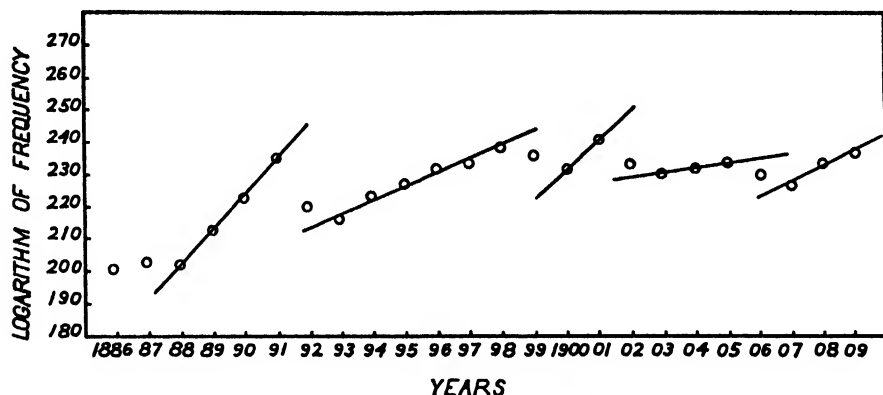


FIG. 3. THE PARTRIDGE (*PERDIX CINEREA*) IN GATCHINO

The years from 1886–1909 (25 years) are marked on the abscissa. The logarithms of the numbers of breeders are marked on the ordinate. The regularity of the disposition of the points in relation to the straight lines shows the regularity of the yearly growth, interrupted by periodic plagues.

frequency of the encounters between the predatory birds and their prey causing the infection of the healthy individuals is a function of the number of partridges, therefore the frequency of the infection and the mortality rate must decline with the reduction in the numbers of the herd. This is exactly what happens in reality. In the first year of the plague there perished on the average 40 per cent of the whole number of breeders, in the second year only 14 per cent.

The index of survival and the mortality rate of the young for other species of birds

ably longer. According to Brehm it has been known to live in captivity for 20 years. The capercaillie attains sexual maturity at a considerably later age than the partridge. It begins to build nests and puts on the definite male attire of an adult cock in the third year of its life; the female lays fewer eggs than the partridge, from seven to nine on the average. In accordance with the smaller value of r and the greater value of j the reproduction of the capercaillie goes on at a slower rate, and in accordance with the duration of its life it needs a longer period of time

for populating its habitat. The partridge reproduces itself more rapidly; the resistance of the individuals being less, the plagues and the frequent exterminations of the population are compensated by the fertility of the birds. At the same time the mortality rate of the young is practically the same for the two species of birds (90-95 per cent of the yearly brood).

Not only birds but also roes (*Capreolus capreolus*) were bred in the Gatchino

not exist in Gatchino, were imported from Germany to the number of 18 males and 19 females; three bucks and six does were supplied from the Oural and two females and one male from the Caucasus; much later, in 1907, three does and three males were brought from Atchinsk. In the beginning the roes were kept in an enclosure. In 1892 forty-one of them were let free into the forest; the data not being available for the years 1893, 1894, 1895, we have

TABLE 2
Dynamics of the Herd of Roes (Capreolus capreolus) in Gatchino

YEARS	NUMBER OF THE ROES IMPORTED INTO GATCHINO	GAME SHOT	NUMBER OF ROES IN THE FORESTS	GROWTH OF THE HERD IN PER CENT OF THE NUMBERS OF PRECEDING YEARS	SURVIVAL OF THE YOUNG IN PER CENT	MORTALITY OF THE YOUNG FOR THE PERIOD "/>
1892	200♂ + 21♀	—	41	—	—	—
1893	—	1	—	—	—	—
1894	—	—	—	—	—	—
1895	30♂ + 6♀	—	—	—	—	—
1896	—	—	59	—	—	—
1897	—	—	72	22.0	30.0	70.0
1898	—	—	—	—	—	—
1899	—	1	127	76.0	64.0	36.0
1900	—	—	160	26.0	61.0	39.0
1901	—	—	204	28.0	57.0	43.0
1902	—	—	287	41.0	55.0	45.0
1903	—	1	321	12.0	27.0	73.0
1904	—	1	425	32.0	64.0	36.0
1905	—	—	498	15.0	28.0	72.0
1906	—	—	635	27.0	57.0	43.0
1907	30♂ + 3♀	1	755	19.0	35.0	65.0
1908	—	—	872	16.0	29.0	71.0
1909	—	6	1068	23.0	48.0	52.0
Mean.....					46.0	54.0

hunting grounds. The results of this breeding are of great interest, representing as they do an extremely rare case of the reproduction of a large mammal during a period of 12 years (from 1895 to 1909) without any shooting and under supervision of the increase of the herd, left to natural conditions in its struggle for life. In the course of the 12 years the herd increased in numbers from 59 to 1068 individuals. The roes, which formerly did

to consider the year 1896 as the first year of reproduction, their number being then 59. The roes in Gatchino, as in all hunting grounds, were registered by tracks left by them in the snow, generally in November or December, when the young, born in April and May, were seven or eight months old, and the first period of the juvenile mortality was over. On an appointed day all guards came out for the registration of the numbers of animals,

each forester counting up the incoming and outgoing tracks in his own district, the total number of the animals in the hunting grounds was calculated according to these data.

The following peculiarities of the roe should be pointed out here. The roe mates in August and the female bears kids in May, the period of gestation lasting nine months. We observe in this case a very peculiar development of the embryo, the egg passing very rapidly through all the stages of division and its development stopping after this for several months, while the formation of the fetus begins $4\frac{1}{2}$ months before birth. Thus we have an obvious delay in the development of the fetus brought about by unknown causes. The period of time needed for the development of the fetus—in reality four to five months—is nearly the same as the period of gestation of sheep or goats, but the whole period of pregnancy of the roe is nearly the same as that of the much larger reindeer, where there is no delay in the development of the embryo. The female attains sexual maturity at the age of 15 to 16 months; at the age of two years she brings forth generally two, rarely three or one kid. According to German observations 20 per cent of the total number of adult females remain barren. The male attains the full development of his horns at the age of three, but sexual maturity sets in earlier, at the age of two, as is the case of the females. However, in so far as at the time of mating the males are fighting for the females, the young roebucks have a chance of partaking in the act of fertilization only in the case of scarcity of the adult males. According to German data the roe ceases to mate at the age of 10, but lives up to the age of 14 or 15 years.

The statistical data for Gatchino do not give us any information as to the number

of the age groups forming the herd, but it is evident that the total number of the roes as given in these data includes the adults of two or more years, the young above one year, as well as the brood of the year minus those that had perished before the moment of registration, the analysis of the registration showing that the subsequent mortality of the brood was not great. I calculated theoretically the growth rate and the age composition of the herd of roes, starting in my calculation from two pairs of adults, the conditions given being the following: parity in the numbers of males and females, 20 per cent of barren females, the rest of the females bearing two kids each from the age of two years upwards. I assumed that 50 per cent of the brood perished before attaining the age of two years, those that had survived the first year surviving also the period of registration. Having plotted the following diagram (Fig. 4) I noted that the curve showing the growth of the herd approximates the theoretical number of breeders and yearlings up to 1903, but that from that year onwards the observed reproduction of the herd fell far behind the theoretically obtained figure.

Comparing this fact with the very low figures of the brood I assumed the slow increase of the growth to be the result of the mortality of the young in the year 1902–1903. The point which in my calculation represented the number of the yearlings was placed so that it corresponded to the point representing the real number of the Gatchino herd and I noted a further coincidence of the figures for the growth obtained theoretically with the empirical curve. This coincidence convinced me that the yearlings that had survived the period of juvenile mortality were really included in the registration, as well as all the other ages; this also encouraged me to calculate the rate of the total increase in

the numbers of the herd, basing my calculations on the constants of reproduction as indicated above, and assuming such a reduction in the numbers of the brood for the first year of life that the total number

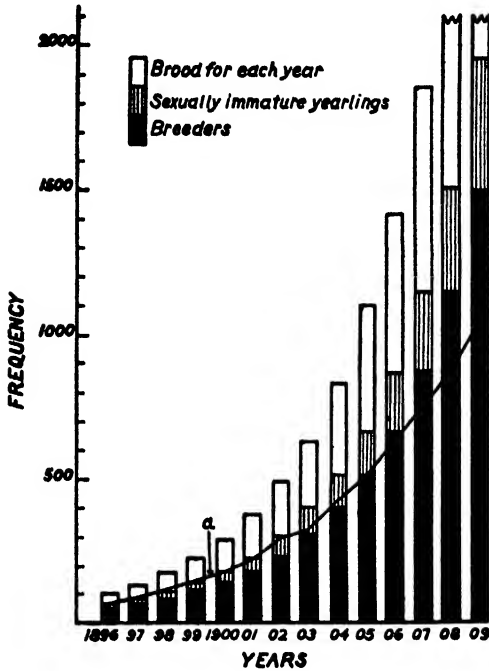


FIG. 4

FIG. 4. GROWTH OF THE HERD OF ROES (*CAPREOLUS CAPREOLUS*) IN GATCHINO

The curve *a*, representing the observed population, is drawn on the diagram of the growth of the herd of roes, calculated theoretically on the basis of the species constants of reproduction: $r = 2$, $j = 2$, $m = 50$ per cent of the new-born young. Initial population = 59; every year 80 per cent of the adult females bring forth young. ($N\sigma^1 = N\eta$). The numbers of the herd for each year are represented by one column. The diagram shows that up to the year 1903 the curve *a* approximates the theoretical number of breeders and yearlings, but that after that year it falls behind the theoretical increase.

FIG. 5. THE INCREASE OF THE HERD OF ROES (*CAPREOLUS CAPREOLUS*) IN GATCHINO

The curve *a* drawn on the diagram shows the observed growth of the herd. The constants used in calculating the theoretical distribution are: Initial number of the Herd— $S_0 = 59$, $r = 2$, $j = 2$, the number of the bearing females = 80 per cent of the adult females; unlike Fig. 4 m (the value for the mortality rate of the brood) is assumed to correspond to the total numbers of the individuals for each year, and the highest limit of the column for the roes of two years coincides with the curve *a*. The diagram shows the numbers of the age groups of the herd of roes in Gatchino for the summer of every year. The delayed growth as compared with that of Fig. 4 is due to a higher mortality during several years.

of the roes was equal to the number shown in the statistical data of the Gatchino hunt (Fig. 5). After having obtained these figures for the herd I further calculated the mean percentage of reduction of the brood. It proved not to exceed 54 per

cent a year. In so far as a certain mortality, the amount of which is unknown to us, certainly took place among the adults, the figure for this mortality may be safely included in the 54 per cent mortality of the brood and the 20 per cent of the barren females. We are deprived of the possibility of determining the rate of

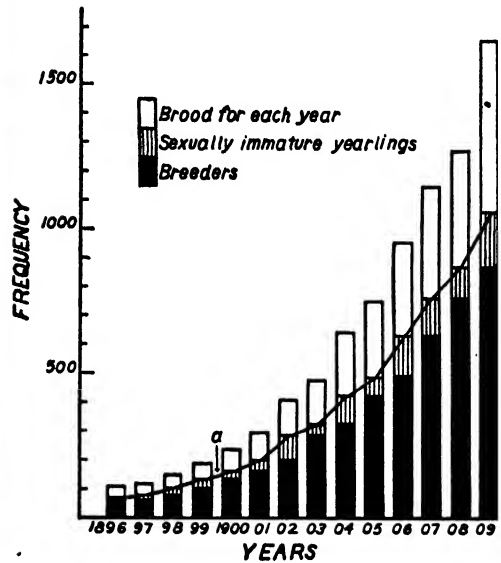


FIG. 5

reduction in the numbers of the adults, but we have to assume that the mortality rate of the brood was about 50 per cent of the number of the young born every year.

I showed in my work of 1930 that the mortality rate of the young during the

period from the birth of the female to the moment of her first parturition must be constant within the limits of each class of vertebrates. We possess for mammals observations of American investigators on the mortality rate among seals (*Callorhinchus alascanus*). The seals lose 49 to 50 per cent of their brood during the first year of life. The mortality rate in the brood of the polar fox is also about 50 per cent. Finally I registered in the winter of 1931-32 the number of wild boars in the National Park in the Caucasus and found that the percentage of the surviving brood of the wild boar was 45.5 per cent if we assume, following Dinnik (1910), that the females bear on the average eight young, in reality probably a little less. If on the average there are seven young borne by the female every year, the percentage of survival rises to 50. Thus we see that the mortality rate among the roes coincides very exactly with the theoretical data. The figures obtained are not sufficiently precise and field investigations are needed. I assumed that 50 per cent of the females remained barren every year; however, this number varies in some measure. The mortality rate of the adult roes, which is unknown to us, probably also varied in the course of different years; nevertheless, the coincidence of the curve obtained theoretically with the run of the empirical curve showing the growth of the Gatchino herd is so striking as to allow us to assume with sufficient security that the growth of the herd in reality follows the exponential curve, determined by the constants of reproduction of the species and corrected for the mortality rate of the brood under the age of the first parturition of the female, the mortality rate of the brood being on the whole equal to 50 per cent of the young born every year.

Applying the method of logarithms to the yearly registrations we conclude

that the growth of the herd followed the exponential curve and we can also make some additional observations. Plotting the registrations on an arithlog grid we obtain an ascending range of points represented in Figure 6. We see that the points follow with great precision a straight line, this being a proof of the reliability of the statistical data. Examining the disposition of the points more closely we find that the deviation of the points can be explained by fluctuations in the mortality rate of the brood in the course of different

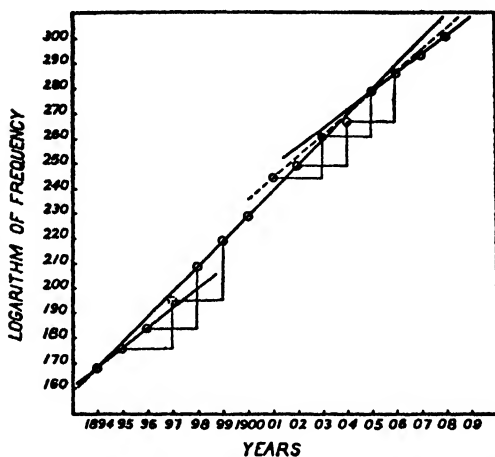


FIG. 6. THE LOGARITHMS OF THE NUMBERS OF THE YEARLY REGISTRATION OF THE ROES (*CAPREOLUS CAPREOLUS*) IN GATCHINO FROM 1894-1909

The years are marked along the abscissa, the logarithms along the ordinates.

years. The data for the year 1898 being lacking, we had to use the logarithm of the numbers for 1897, adding to it the mean percentage of the growth of the herd for the four nearest years (1895, 1896 and 1898, 1899). The straight line passing through the point of the year 1894 connects the points 1895 and 1896. The longest of the straight lines connects the points 1894, 1899, 1900, 1902, 1903, 1905 and intersects at a certain angle the line connecting the points of the last four years. From this we draw the conclusion that the growth of the herd during these

years was a regular one. This growth is represented by the angle of inclination to the abscissal axis of the straight line connecting the points; it amounts to 21 to 22 per cent a year.

The six roes from the Oural added to the herd in 1895 brought forth their first young in the year 1897; this increased the productiveness of the herd, upsetting the normal proportion of males and females in favor of the females. But we might just as well have assumed a higher percentage of survival of the brood of that year. At any rate the course of the diagram changes; the percentage of growth for the years 1899, 1900 and 1901 is higher than for the first three years, and the points are disposed according to some new law.

In 1902 we observed again a very high percentage of yearly growth, obviously due to the high percentage of survival of the brood (40 per cent in 1901), while in 1903 the percentage of growth is lower again; this can only be explained by the high mortality of the brood. The results of the great increase in numbers in 1902 and of the small one in 1903 are noticeable in the yearly growth in 1904 and 1905, when the females born in 1902 and 1903 bred in their turn; the yearly increase of the next years is more constant. During the last four years from 1906 onwards the increase goes on regularly at a rate approaching that of the growth of the herd for the first five years. The high percentage of survival for the year 1902 was counterbalanced by an increased mortality and by a low rate of growth in 1903 resulting from the high percentage of mortality of the brood. As a result of this the number of the herd attained in 1906 was the same as it would have been if the increase had been going on at the rate of the years 1895-1899.

We have to note one more regularity in the disposition of the points of the dia-

gram. From the year 1898 onwards every point can be connected with the next but one: 1898-1900, 1899-1901, 1900-1902, etc. The population of the roes was registered in Gatchino in November or December of every year; thus the yearlings were registered at the age of seven to eight months, when the period of juvenile mortality was over. The roes mated in August of the following year and the females bore young the following spring after having attained the age of two years; their brood in its turn was registered the following winter at the age of seven to eight months. Thus the connection of each point with the next but one finds its explanation in the age of the first parturition of the female.

The statistical data concerning the population of roes break off in 1909. We do not know what happened after this, but at any rate there were no plagues.

The dynamics of the numbers in the herd of roes shows that the reproduction of a population of vertebrates follows in real life the exponential curve, as determined for each species by the constants of reproduction of the species and by the rate of juvenile mortality. For birds we determined the mortality of the brood as about 90-95 per cent of the total newly hatched brood, for mammals as about 50 per cent of the total new born brood. We certainly cannot expect the precision of these figures to be quite satisfactory and further investigations must be organized with the object of determining the rate of reduction in the numbers of the adults, but in any case the possibility of an analysis such as we have made is in so far interesting as it indicates the possibility of exactly foreseeing the increase of the herd and the construction of the curve of its growth according to constants of reproduction of the species with a correction for juvenile mortality.

We have to draw one more important conclusion from our observations on the rate of reproduction of the roe and of the partridge, this conclusion being confirmed by observations on the growth rate of herds of other animals and birds not mentioned in this paper and also by the relative numbers of groups of fishes (Baranoff, 1917). These observations have a general significance. The yearly reduction in numbers of each older group is fully compensated by the increase in the numbers of the following younger group,

capercailies in Gatchino. The brood was registered every summer, and the adult males every spring on the gathering places for mating. The registration on the gathering places included the adult birds above three years of age, the capercailie attaining its sexual maturity in its third or fourth year; thus only the birds that had survived the period of juvenile mortality were included in the registration.

Comparing the diagram of the registration of the males on their gathering places in spring with that of the females and of

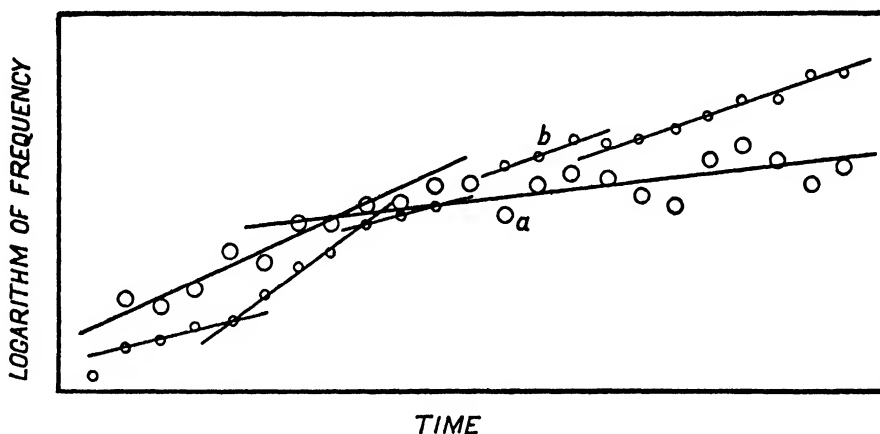


FIG. 7. GROWTH OF A POPULATION OF CAPERCAILIES

a. Logarithms of the registrations of the capercailies on the nests (the sexually mature female brood of each year). *b.* Logarithms of the capercailies on the gathering places (the sexually mature individuals). The points in *b* show a smaller deviation from the straight lines than the points in *a*; this can be the case only if the deviations in the mortality rate of the first and of the second winter stand in an inverse relation to the mortality rate of the spring and of the summer of the first year; the result of this being a more equal growth of the herd of the adults.

consequently the curves of the mortality rate of the land vertebrates and of the fishes correspond to the different age groups forming the herd. Owing to this fact the herd increases in numbers regularly and the current notion that one pair of progenitors is replaced by one pair of descendants proves to be an erroneous one. The regularity of the exponential curve, showing the increase in numbers of the adults in the herd, is caused by the phenomenon which we have observed while studying the rate of reproduction of the

the young birds in summer (Fig. 7*a* and *b*) we see that the points representing the males lie closer to the straight line than the points representing the females and the young birds, the latter forming several easily discernible waves. The natural levelling out of the curves of the adult birds can take place only as a result of corresponding fluctuations in the percentage for the figures of early mortality of the brood. The mortality in the years following those when the spring is favorable and the brood numerous will be high and

after an unfavorable spring, the numbers of the brood declining during the summer, the mortality, probably in the course of the following winter, will be less. As a result of this the increase in the number of the adults goes on with greater regularity owing to inverse fluctuations in the intensity of the mortality of the brood at an early and at a later age. The biological aspect of this phenomenon is hardly known, but the fluctuations in the mortality rate probably depend on the changes in the numbers of the predators. The curves showing the shooting off of the predators correspond to the curves in the numbers of the game. It is chiefly the young birds, which have not yet attained their full maturity, that are caught by the claws of the predators, while the older birds escape them more easily. It is highly probable that the fluctuations in the mortality rate are determined precisely by these correlations between the number of predators and the number of prey according to the qualitative differences between young individuals and adult ones. This levelling out of the curve can also be observed in connection with the roe. Thus we come to the following schema: the mortality of the brood per year is about 90 per cent for the birds and 50 per cent for the mammals. The group of the sexually immature surviving individuals and the herd grows regularly during a certain period of time, characteristic for the species. This growth stops abruptly after a plague, affecting not only the brood but the adult individuals as well, and after such a plague a new cycle of reproduction sets in.

Certainly such a simplified cycle represents only a schema of the phenomenon and in reality the process is a much more complicated one. Sometimes the depression is being levelled out; sometimes, given certain constants of reproduction, the

depressions are too considerable to be levelled out in the course of one year. The depressions are brought about by different causes and the rate of reduction in the number of the herd may be different. Thus we did not observe any depressions in the given period in the case of the less fertile and comparatively long-lived capercaillies, whereas in the case of the partridge the depression is plainly marked. The reduction in the numbers of the adult individuals, as well as the increase in the numbers, evidently follows the exponential curve. The graph for the partridge shows that the descending range of points is disposed on the straight line as regularly as the ascending one. We can note, without referring to the corresponding diagram, that the depressions take a more rapid course when they affect more fertile species and a slower course when affecting less fertile ones.

REDUCTION IN THE NUMBERS OF THE HERD

We have found that the increase in numbers runs according to a geometric progression determined by species constants of reproduction with a correction for the rate of juvenile mortality for the period j and we have shown, for several examples, that the increase in numbers is abruptly interrupted as a result of periodic plagues caused by abiotic factors or epizootics. A plague resulting from abiotic causes obviously lasts as long as the effect of these causes, for instance, as long as an inundation, as the scarcity of food after a deep snowfall or a dearth; but a plague resulting from an epizootic can last much longer. If the spreading of the disease depends on the density of the population, causing the transmission of the infection, a greater sparseness of the population reduces the possibility of infection, and the disease will gradually slacken. This happens

both in cases of a direct transmission of the infection and in the more complicated cases of infection by helminth parasites with intermediate hosts.

Such infections as pest or anthrax can exterminate an enormous mass of animals in the course of one to two months, but some diseases, and among them evidently the helminth invasions, sometimes spread less rapidly and the rate of reduction can be detected even if the registrations are carried out only once a year. One of the greatest modern mathematicians, Volterra, has developed a theory of the fluctuations in the number of the predators and of the prey, stating that the variations in the numbers of the species preyed upon depend on the number of encounters between these two species. By the word "predators" Volterra means not only quadrupeds and birds, but also agents of disease, and he shows that in this last case the reduction in the numbers of the prey runs according to a negative exponential curve or to a declining geometric progression. The study of the graph for the partridge shows that the reduction in the numbers of the herd as well as its growth actually follows this law, the points of the curve being disposed along a straight line. In reality the process is much more complicated than the case analyzed by Volterra, the reduction in the numbers covering several years and the number of partridges increasing every summer as a result of natural reproduction, whereas Volterra assumes that reproduction is going on uninterruptedly throughout the year.

It is interesting to note that the rate of reduction may be different for different species; for long-lived but not fertile species the period of the reduction in numbers can spread over several years, as is shown by the curve representing the reduction in numbers of the aurochs in the forest of

Belovcuj in the seventies of the last century.

Thus our observations seem to corroborate the theses of Volterra, although some of his premises rather simplify the question and do not exactly square with the complicated biological relations observed among populations of mammals and birds in nature.

Observations on the rate of reduction in the numbers of the brood in our possession are very scarce, but there are certain indications tending to show that this reduction also follows the law of Volterra. I carried on during two years the registration of the summer brood of the black grouse in the forest of Bashkiria in South Ural (S. A. Severtzoff, 1932). The reduction in the mean numbers of the young birds in each nest proved in this case to follow a descending geometric progression.

According to data from the literature supplemented by observations carried on in the National Park of Bashkiria I assumed the mean value of each clutch of the capercaillies to be eight eggs. The mean number for each brood for July proved to be 4.63, for September 2.82 in 1930 and 2.87 in August, 1931. The data for Gatchino have shown that 90 per cent of the number of birds registered in June and July perish during the winter, thus in our case only 0.463 survived till the age of sexual maturity. Taking the logarithm of these figures, I obtained the diagram (Fig. 8) showing a very regular disposition of the points along the straight line. Further closer observations are certainly needed but in so far as figures are exact we see that the reduction in the numbers of the brood follows a negative exponential curve, the run of which has to be reconstructed according to the diagram; the reduction in the numbers attains its lowest ebb in the spring of the following year, after

this a new cycle of reproduction sets in. A series of observations carried on in the Bashkirian forest shows that the killing off of the birds has to be attributed in the first place to birds and beasts of prey and we see that in this case, as is to be expected according to Volterra, the reduction follows the negative exponential curve, although the biological relation in reality is a different one. Volterra admits an uninterrupted growth of the numbers of the predatory species and a corresponding

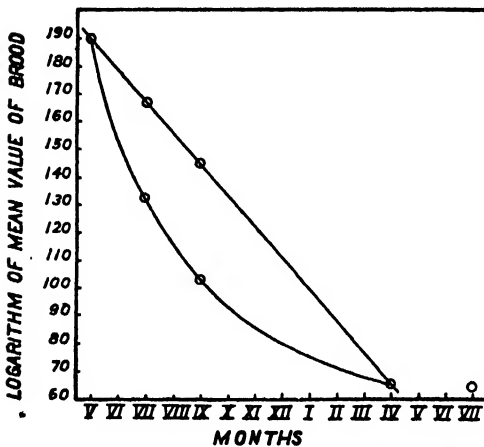


FIG. 8. DIAGRAM OF THE BROOD OF CAPERCAILLIES IN THEIR STRUGGLE FOR LIFE

On the abscissa are marked the months from May to July of the following year; on the ordinate, the logarithms of the mean value of the brood for the corresponding months. The curve *b* is a negative exponential curve of the decline of the numbers built up according to the curve *a*.

synchronous decline in the numbers of the prey, but in our case the brood of the predatory birds and animals is brought forth in spring at the same time with the game. During the rest of the year the game is dying off and probably the brood of the predators as well. This process comes to an end before the beginning of a new cycle of reproduction.

In normal years the reduction in the numbers of the individuals that have attained sexual maturity is fully compen-

sated by the young birds, sexually immature, and the following year the group of breeders, both game and predators, will be growing in numbers. This growth goes on until the species of herbivorous animals are exterminated as a result of abiotic factors or of epidemics. The extermination of the prey brings about the dying off of the predatory birds and animals in consequence of the scarcity of food. This picture in real life is much more complicated, the predatory animals being generally euryphagous and not all species of prey perishing simultaneously. But the works of Preeble, Thompson Seton (1909) Elton (1927) and others show that the dying off of the predatory species is connected with plagues among animals forming their chief food. Thus the cycles of growth and of decline in the numbers of the population of herbivorous animals and of the predatory species which feed upon them must coincide more or less.

All the above allows us to build up the following schema of the dynamics of population. The herbivorous animals that have survived a plague bring forth issue in the spring. The dying off of this issue goes on in a declining geometrical progression during the period *j* (for many species this is equal to one year). The surviving brood increases the group of the breeders, the growth of which during a series of years follows the positive exponential curve, as determined by the species constants of reproduction and by the mortality in the first year of life. The length of the period of growth of the herd is determined by the constitution and by the biology of the species as it is precisely those characters of the species worked out in the course of the preceding evolution which determine the amplitude of the fluctuations from the optimum of the conditions of the environment that can be borne by the animal without detriment. The

growth in numbers is interrupted by the next depression in abiotic factors. If such a depression is late in coming and the population goes on increasing, the factors favorable for the development of parasitic agents of disease are gaining in strength together with the growing density, and the growth of the herd is cut off by an epizootic.

Owing to this fact the reproduction of the herd as well as the dying off of the yearly issue follows a negative exponential curve; the mortality affecting the adult animals as well, the number of the herd reaches its lowest ebb; after this a new growth of the herd sets in. The curve representing the dynamics of the carnivorous species preying upon the herbivorous ones runs parallel to that of the herbivorous species and the cycle of growth of the herd may be of the same length, but in some cases when the predatory animals can migrate in time into an area where the plague is not yet developed, or when they can be content with a substitute food, there may be deviations from the rule.

BIOLOGICAL CAPACITY OF THE HABITAT

Thus far we have spoken only of the processes of the increase and of the decline in the numbers of the herd in time, without discussing the important problem of the biological capacity of the habitat occupied by the population. But the numbers of the population of different species in the same locality are different, and therefore the absolute number of the individuals needed for attaining the highest density for any species will be a different one for each species.

The increase of the herd goes on in a geometrical progression, as determined by species constants of reproduction; it is so intense that all species, even the least fertile ones, fill in the area suitable for their habitation in a very short period of

time. Travellers investigating countries hardly changed by the interference of man describe herds consisting of millions of animals of slow reproduction, such as the bison in the prairies of America, and enormous flocks of seals. Darwin wrote that the albatross, the reproduction of which is very slow, is perhaps the most numerous bird on earth; we can also mention the immense flocks of the migratory dove and lastly the enormous number of ungulates in Africa in the beginning of the last century. All these examples show that the absolute number of any species may be very great in spite of its relatively low fertility.

CORRELATION BETWEEN DURATION OF LIFE AND FERTILITY

In my paper of 1930 I proceeded from the idea that the duration of life of each animal determines the limiting number of the generations which can exist simultaneously in the habitat of the species. Those individuals that have survived the period of juvenile mortality forming a stable population, the duration of life of the individuals of each species must correspond to the period between two consecutive plagues, this period being characteristic for each species. Proceeding from this idea I studied the relation between the duration of life and the fertility of mammals. I have calculated the correlation between the index of the species fertility q and the species duration of life T . I reasoned as follows: Let the number of pairs of individual breeders that have survived the plague be S_0 , the number of the individuals to the end of the cycle of reproduction t will be S_t ; then we can write

$$S_t = S_0 q^t.$$

Consequently S_t is directly proportional to S_0 and q^t . After putting this expression

in logarithmic terms and transferring $\log q$ and $\log S_0$ to the left side we write:

$$\frac{\log S_t - \log S_0}{\log q} = t,$$

or if

$$\log S_t - \log S_0 = \log \frac{S_t}{S_0} = \log W,$$

then

$$\frac{\log W}{\log q} = t.$$

$\log W$ represents the intensity of the plague, $\log q$ the rate of growth of the population, t is the time interval in which S_0 grows into S_t . From the equation

$$\frac{\log W}{\log q} = t,$$

$\log W$ is directly proportional to t and inversely proportional to $\log q$. If $\log q$ is constant and t and W variable, we can say: the longer is t , the greater is the density attained by the population and the stronger is the plague

$$(S_t/S_0 = W).$$

If t is a constant (and we tried in our work to show that the period of growth of the herd must be a very constant one) then the left side of the equation

$$\frac{\log W}{\log q} = t$$

must also be constant; this is possible if $\log W$ and $\log q$ change in inverse proportion. During the period between the two great plagues which bring S_t to S_0 there occur depressions of a smaller intensity, which upset the rate of increase of the herd and put off the time when the number S_t can be attained.

While examining the rate of reproduc-

tion of the roe and of the capercaillies we have seen that the high mortality setting in from time to time is accompanied by the corresponding increase of the fertility of the herd. This increase is obtained either indirectly by the reduced mortality rate among the brood or else directly by the increase in number of the young brought forth by the females and also by a lower percentage of barrenness of the females, in other words by the increase in the numbers of the issue brought forth by the herd as a whole. The last case is specially important for species which do not bear every year, but after longer intervals of time, as the aurochs (*Bison bonasus*).

We do not know whether the violence of the plagues has undergone any variations in the course of evolution or not, but there seem to be some indications pointing to the reduction of the violence of the fluctuations in the course of evolution; the decline in the numbers of fertile rodents, hares, and lemmings, was evidently much more considerable than the 60 per cent found in Gatchino for the herd of partridges, but the data available are not sufficiently precise.

Assuming the duration of life of the individuals to correspond to the frequency of the plagues, it is possible to show that the fertility is reduced in accordance with the growing longevity during the evolution of species. For 78 species of mammals the coefficient of correlation between the duration of life of the species T and the logarithm of the index of the species fertility q is -0.899 ± 0.0238 , but it is obvious that the species evolved divergently and that in the course of evolution some of them acquired a greater longevity, and others a smaller one, their fertility varying according to the equation

$$\frac{\log W}{\log q} = T.$$

LAWS OF VOLTERRA

We have repeatedly mentioned in this paper the works of Volterra, pointing out that his fundamental conclusions are corroborated by observations on the rate of reproduction of the vertebrates and it is proper to cite in this place his essential theses (Volterra, V., 1930).

1. The law of the periodic cycle: The fluctuations in the numbers of both species are periodic, the period being determined by the rate of growth and of reduction in the numbers of the population and by the original ratio of the numbers.

2. The law of conservation of the mean number: The mean number of individuals of both species remains constant; as such it is determined by the initial number as long as the rates of growth and of decline in numbers (birth-rate) remain stable and as long as the coefficients of defense and aggression remain invariable. This means that both species fluctuate about a state of statistical equilibrium which is never attained, the mean number for each species being assumed to be a constant one.

3. The law or rule of the disturbance of the mean value: When there is an attempt to kill off individuals of both species in equal proportions, the relative numbers of the species preyed upon increase and those of the predatory species will be reduced. The diminution of killing of the species preyed upon also increases the number of the predatory species.

The following laws can be applied to cases when the fluctuations are not great: 1) small fluctuations are isochronous, which means that the period of these fluctuations does not depend in a noticeable way on the initial number of the individuals and is solely determined by the correlation between the coefficients of defense and of aggression; 2) the period of the fluctuations is proportional to the geometric mean of the periods of time

during which the first species doubles its numbers and the second one is reduced to half its numbers; 3) in the case of equal fluctuation—the population being reduced by an equal number of individuals during equal periods of time—the killing off of the individuals of the carnivorous species accelerates the fluctuations, while the reduction in the numbers of the species preyed upon delays it.

Our observations show that the growth of the herd follows the exponential curve determined for each species by its constants of reproduction. The reduction of the herd in so far as it depends on biological agencies also follows the negative exponential curve, as was admitted by Volterra, but the general picture of the fluctuations, in the numbers of vertebrates at least, is different from the picture suggested by Volterra. The curves of growth and of reduction of the herd are not symmetrical; the curve of growth is a more slanting one, that of reduction a more rapidly descending one.

The quadruped beasts of prey do not reduce the number of the herbivorous species periodically as is supposed by Volterra. The numbers of the carnivores increase with the increase in the population of the herbivores and they die off simultaneously with the latter. Volterra's theory of uninterrupted fluctuations is probably right in connection with epidemic diseases caused by parasites, when the infection is a function of the number of the herd and of the frequency of the encounters between the infected and the uninfected individuals.

We can evidently point out another very interesting circumstance which, however, has still to be verified and further investigated. According to Volterra, if the predatory species and the species preyed upon are killed off in an equal measure by any third cause, as for instance

by man, the numbers of the predatory species fall lower than the numbers of the species preyed upon. This is quite natural biologically, the number of the predatory species being reduced not only in consequence of their direct extermination but also in consequence of the scarcity of food resulting from the killing off of the herbivorous species.

The correlation table between the duration of life and the fertility of mammals (S. A. Severtzoff, 1930) shows that, the duration of life being equal, the predatory species possess a greater fertility than the species of herbivorous animals they feed upon. At the same time we know that the relative numbers of the predators are always less than the numbers of the herbivores. This contradiction between the coefficient of potential fertility and the relatively small numbers of the carnivorous species makes us assume that the mortality rates of the brood and of the adults are higher among the latter species than the same rates among the herbivores, the predators perishing not only from causes bringing about their own extermination, but also from causes exterminating the species they feed upon. The smaller resistance of the predacious species against agencies of the environment is compensated by a greater fertility. We can see in this fact a biological phenomenon worked out in the course of evolution and levelling out the effects of the law deduced by Volterra on the basis of a theoretical analysis of the problem.

SUMMARY AND DISCUSSION

1. The numbers of each species of animal are not constant but increase yearly as a result of natural reproduction on an exponential curve determined by the inherited characters of the species with a correction for the mortality of the yearly brood and of the adults.

2. The mortality rate of the brood is about 90 per cent for the birds and 50 per cent for the mammals, this reduction covering on the whole the yearly reduction in the numbers of the adult breeders.

3. The reduction in the numbers of the brood follows the negative exponential curve.

4. The increase in the numbers of animals of any species is cut short by plagues, caused by abiotic factors after certain periods of time characteristic for each species and determined by the capacity of the species to withstand extreme deviations of external conditions from the optimum; after these plagues the reproduction of the species goes on according to the former law.

5. In order to secure the survival of a number of individuals sufficient for the continuation of the race, the species have to attain their highest possible numbers in the course of the period favorable for reproduction.

6. If the density of the population is not decreased in time by abiotic factors, it will be decreased by an epidemic disease, the higher density of the population being favorable to the spreading of the epidemic.

7. The predatory species only delay the increase in the numbers of the herbivorous species, exterminating the greater part of the yearly brood, but they do not interrupt the growth. Diseases caused by parasitic agents reduce the numbers of the vertebrates; in this case the reduction follows the negative exponential curve and lasts till the numbers of the herd have attained a certain minimum.

From this picture we may derive some conclusions about the evolution of fertility. The question being a very complicated one, we intend to devote a special article to its analysis and we shall confine ourselves here to general conclusions.

The constants of reproduction of the

species as well as the mortality rate among their brood and among the adults vary in the course of evolution. Comparing different species, as is done in comparative morphology, we can imagine the evolution of the biology of the species. There is a different curve of the mortality rate corresponding to each given moment of the existence of the species and also a different cycle of growth and of reduction in the numbers of the herd, the reduction in numbers being compensated by the fertility of the species and corresponding to the longevity of the individual as characteristic of the species.

This balance is only an apparent one, and the species are undergoing unceasing variations as a result of the struggle for life; we shall be able to show this on the existing fauna when we have acquired the means of comparing more minutely and with greater precision the fertility and the longevity of kindred species and perhaps of different colonies of the same species. The adaptation of each species to the condition of the environment is increasing in the course of evolution. Since each degree of growing adaptation increases the survival of the individuals, they acquire a greater longevity. The number of individuals existing in the herd at any moment is growing in this case as a result of the birth of young individuals and also of a greater duration of life of the adults. There are different factors entering into this growing adaptation. For instance: 1) increased resistance of the individual to abiotic factors resulting in the lengthening of the period between two plagues caused by abiotic factors; 2) improved equipment of the prey for defense resulting in a lower percentage of killing by predatory species; 3) improved equipment for aggression of the predatory birds and beasts and their greater ability to procure food, bringing about a

lower percentage of survival of the corresponding species preyed upon and this in its turn resulting in a higher mortality of the predators, etc. On the whole a higher adaptability must prolong the duration of life of the individual.

But the cycle of growth in the numbers of the population will hardly be lengthened and this newly acquired duration of life hardly takes place as both these phenomena reinforce the conditions of the development of infectious diseases which in their turn interrupt the growth of the population as soon as it attains a certain limit; consequently the infectious diseases prolong the cycle of growth of the herd and only the populations with a reduced fertility will be able to prolong the biological duration of life of the individual beyond these limits.

A reduced fertility of the population is acquired in some cases owing to a higher age of the first parturition (j) and to a longer period between two consecutive births (p). But the reduction in the numbers of the brood must be the predominating factor in the cases when the species are breeding at the age of one year. Thus the agents of epidemics are causes of the selection of the least fertile populations, when the same result is not attained by the evolution of individual development. Finally it is necessary to point out that the mortality rate of the brood must increase as a result of a greater competition with more numerous and fully developed adult individuals. All these causes must act as factors delaying the progressive evolution of the species.

Further we can imagine the process of the shortening of longevity in the course of evolution as a result of an increasing frequency of plagues from abiotic factors or as a result of a higher coefficient of predacity of carnivorous animals.

The growing frequency of climatic de-

pressions, as at the approach of the glacial period, can be survived only by fertile species or by species with an increasing fertility which succeed in restoring their former level in periods of time shorter than formerly. I am inclined to think for many reasons that this is rarely the case.

Of greater significance is the second case: Volterra's higher coefficient of predacity—an increasing extermination of herbivorous animals by predators; the phytophagous must either acquire a greater fertility or they must disappear from the face of the earth. The following arguments seem to be conclusive that such a secondary increase of fertility due to secondary causes took place among the mammals: the reduction in the numbers of the young borne by the female corresponds to the reduction of the milk-glands. We find that the milk-glands of primitive mammals were very numerous (the *Centetes* had up to 24 pairs, while the fertile rodents have not more than 6-8

pairs); consequently a process of reduction of the brood and of prolongation of longevity has taken place among their ancestors. The fertility of mice and hares is very great as they breed several times a season and some of them attain sexual maturity so early that they breed in their turn during the same summer when they were born. This phenomenon is a secondary one and it corresponds to an increase of fertility due to secondary causes and compensating the growing extermination by predacious animals and a lower duration of life of the individual. According to this the reproduction of the rodents is so rapid that their duration of life does not coincide with the frequency of the climatic depressions and that these species generally perish as a result of periodic epizootics. Thus the most characteristic factors in the biology of the rodents, of the ungulates and of the predatory species find their explanation in the evolution of the ecology of reproduction.

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MOVEMENT IN THE CYANOPHYCEAE

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THE autonomic movements of filamentous Cyanophyceae have attracted the attention of numerous investigators from the time of Adanson (1767), and have evoked a considerable literature describing the visible character of these movements and attempting to explain their as yet cryptic cause. Among the early algological records are the observations of Vaucher (1803) dealing with movement in the young filaments of *Nostoc* and the writings of Schrank (1823) and of Borys de St. Vincent (1827) describing the motility of *Oscillatoria*. The latter author, after presenting a vivid and somewhat amusing description of the behavior of "Oscillaire" filaments, was obliged to conclude with the remarks: "Nous avons renoncé à trouver leur mode de reproduction, et surtout à expliquer le mécanisme et les raisons de leurs mouvements." Exactly one century later one may read in West and Fritsch's (1927) excellent treatise on the algae that "although these movements have been much studied, especially those of the Oscillatoriaceae, no convincing explanation as to the mechanism has yet been offered."

The early workers were concerned with descriptive morphology and taxonomy rather than with the acquisition of knowledge by experimental methods. It should be pointed out, furthermore, that in many instances problems such as this are not solved until a considerable background of general information has accumulated and suitable methods for experimentation have

been devised. The problem of movement in the blue green algae, however interesting to botanists, was not approached experimentally until comparatively recent years.

The motility of the Cyanophyceae is of itself interesting, and the more so because of the striking similarity between this particular type of movement and that exhibited elsewhere in nature, *i.e.*, the locomotion of thiobacteria, diatoms, and desmids among plants, and the movements of amoebae, gregarines, phagocytes, etc. in the animal kingdom. All these relatively simple structures exhibit no permanent organs specialized in relation to locomotion; it is quite possible that no great dissimilarity exists in the fundamental mechanisms which activate them all, though the controlling influences may be different in specific instances. It is our purpose here to bring together the results from the scattered literature pertaining to this subject, and to consider the problem of the mechanism of the movement.

NATURE OF THE MOVEMENT

Several different aspects of movement are apparent in the filamentous Cyanophyceae, *i.e.*, linear translation, axial rotation, and oscillation (*cf.* West, 1916). The translatory type of movement commonly consists of a slow gliding of the filament over a solid substratum in a straight or spiral line, the direction of which may be subjected to sudden and repeated reversal. According to Borzi (1886) the hormogones

of *Lyngbya*, *Plectonema*, *Nostoc*, *Rivularia*, *Scytonema*, and *Stigonema* emerge from their sheaths and exhibit periodic movement in a straight line for short periods of time; but the filaments of *Microcoleus*, *Oscillatoria* and *Spirulina* are characterized by persistent movement in a spiral path. Characteristic linear progression of either the hormogones or the ordinary filaments of these and other genera (*Anabaena*, *Cylindrospermum*, *Gloeotrichia*, *Isocystis*, *Phormidium*, etc.) have been described by many persons (Corti, 1774; Meyen, 1839; De Bary, 1863; Schwendener, 1894; Brand, 1903; Phillips, 1904; etc.).

This typical linear progression is in some instances (especially in the Oscillatoriaceae) accompanied by continuous rotation on the axis of the filament. The direction of rotation, to the right or left, is held to be constant for a given species of *Oscillatoria* (Schmid, 1921) and has indeed been employed in the description of species in Geitler's taxonomic treatise on the group (1925). The manner of rotation outwardly suggests the characteristic rotatory powers of flagellates, ciliates, rotifers, etc. and may be determined by the definite morphology of the organisms. Through failure of all parts of a filament to cooperate, torsion may result in the twining of the *Oscillatoria* filaments about various small objects or each other (Fechner, 1915; Schmid, 1918). In *Spirulina* there is a well-marked rotation about the axis of the spirally twisted trichome during its screw-like progression through the water (West and Fritsch, 1927). Certain species of *Oscillatoria* exhibit a bending of the apical cells which is evident during rotation of the filament. Observations seem to indicate that rotation probably does not occur in the heterocystic members of the group (Borzi, 1886; Harder, 1918; Castle, 1926; etc.) and probably not in all species of *Oscillatoria* (Crozier and

Federighi, 1924). It is probable that the spiral course characteristic of many members of the Oscillatoriaceae while moving freely in suspension may be considerably modified under conditions where the organisms are caused to adhere to a solid substratum.

The third type of movement has to do with the bending and swinging of the end of a filament in a conical path. The swinging of a free end frequently occurs while the other end is held in a colonial mass of the organisms, but may also be found in unimpeded, creeping filaments. Also a bending of the extreme apical portion is commonly exhibited. When the motion is artificially restricted to a narrow plane, as is usually the case in a microscopic preparation, there is presented the appearance of slow pendulatory oscillation which has doubtless given rise to the generic name, *Oscillatoria*. These swinging movements have been related to unequal stretching of the cell membranes on opposite sides of the filament correlated with a simultaneous rotation of the trichome (Schmid, 1918).

Autonomous movements have upon several occasions been ascribed to single zoospore-like cells of the blue green algae (Borzi, 1880; Davis, 1894; Zukal, 1894), but such reports have been few and are perhaps of somewhat dubious authenticity. Recently the detachment of motile blue green cells from the apex of *Oscillatoria* and their swimming about in zoospore-like fashion has been reported by Spearing (1932). The correct interpretation of these reports is as yet by no means clear.

Of these various types of movement, that of longitudinal progression is probably best suited for experimental analysis, since it has been shown to be very steady under constant conditions (Crozier and Federighi, 1924). The rate of movement

under favorable conditions varies in different species up to a maximum of about 2 to 5 microns per second at ordinary room temperature (cf. Gicklhorn, 1921; Crozier and Federighi, 1924; Castle, 1926; etc.). Unlike the simple linear progression of *Nostoc*, *Anabaena*, etc., the trail of an

The situation may be elucidated by the diagram in Figure 1 showing a camera-lucida sketch of the trail made by a filament of *Oscillatoria sancta* creeping on the surface of nutrient agar. The alga was started at the point X, with the filament axis perpendicular to the rays of incident

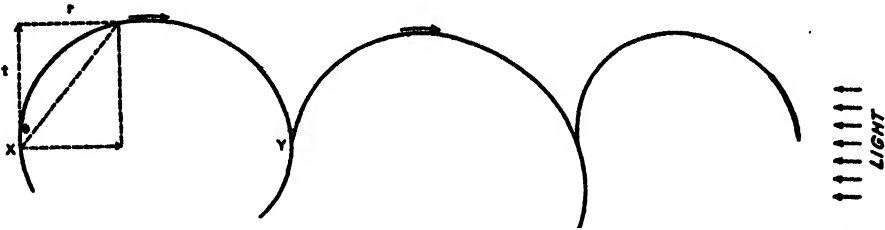


FIG. 1. THE TRAIL OF *OSCILLATORIA SANCTA* CREEPING ON 1 PER CENT AGAR TOWARD THE LIGHT. The angle θ denotes the deviation from a straight line resulting from the combination of longitudinal movement (r) and axial rotation (p).

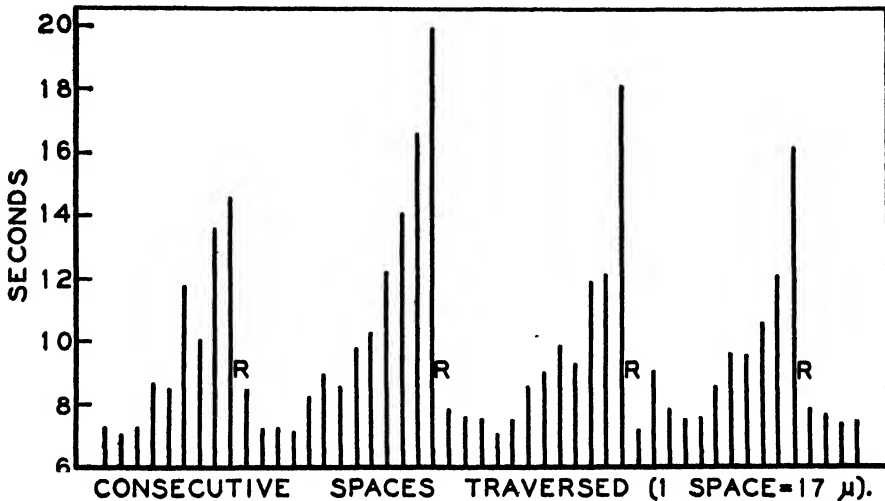


FIG. 2. VARIATION IN VELOCITY OF TRANSLATORY MOVEMENT ASSOCIATED WITH REVERSAL OF DIRECTION IN *OSCILLATORIA FORMOSA*.

The speed gradually decreases prior to reversal and suddenly increases immediately afterward in rhythmic fashion. If a reversal be denoted by R, the succeeding ocular spaces (17μ each) are traversed in 8.6, 7.2, 7.2, . . . 16.5, 19.9 seconds. Following this gradual decrease in speed, a sudden increased velocity re-occurs upon reversal (R); etc.

Oscillatoria filament appears under close examination to assume the form of a curved path. According to Schmid (1921) this path is the result of two vector components, one associated with the longitudinal velocity and the other with the rate of axial rotation at right angles to the filament.

light coming from the right. In this instance the direction of axial rotation was to the right, hence the filament progressed in a curved course until the position Y was attained. At this spot reversal occurred and the filament, always turning to the right, moved again nearer the source of illumination by a curved route. The

shape of the curve may be stated simply to be dependent upon the component of linear translation, t , and that of revolution, r , about the filament axis. The angle θ may be taken to represent the deviation from a straight line, and $\tan \theta = r/t$ or $\pi d/t$ (d = diameter of the filament). This type of observation might very well be employed in the further investigation of the effect of controlled variables upon orientation and reversal of these organisms.

STRUCTURE OF THE ORGANISMS

It is beyond the purpose of this paper to deal with details of morphological and cytological structure in a comprehensive manner, but a few essential facts will be pointed out in order to clarify the possible relationship between structure and certain physiological processes in these organisms.

The question of cell structure in the Cyanophyceae has long been a subject of controversy, but the general situation is fairly well established for those members of the group with which we are here concerned. The protoplast is described as consisting of three regions: a central mass of not very highly organized chromatin material, a peripheral portion which contains the characteristic pigments, and the outer plasma membrane in direct contact with the cell wall (*cf.* Olive, 1904; Gardner, 1906; Guillermond, 1906; Brown, 1911; *cf.* Sharp, 1926; etc.). Cell division is accomplished essentially by amitosis, which results in the quantitative separation of the chromatic material (*cf.* Smith, 1933), and the formation of a ring-like wall which grows inward from the lateral wall. The pigments chlorophyll, carotin, phycoerythrin, and phycocyanin are distributed throughout the peripheral undifferentiated chromatophore mass in diverse proportions (Boresch, 1921; Wille, 1922) dependent upon the

wave-length and the intensity of the illumination (Gaidukov, 1903; Harder, 1923; Sargent, 1934) and the nutrient conditions (Magnus and Schindler, 1912; Schindler, 1913; Boresch, 1920, 1921).

Since the Cyanophyceae are not characterized by definitely differentiated chromatophores, such as hold the pigments in most other autotrophic plants, these algae appear to afford certain distinct advantages as material for the study of photosynthesis. It is suggested that the substances concerned in the reactions of photosynthesis are in this instance relatively free to diffuse throughout the pigmented region which is uncomplicated by differentiated structure. However, there exists the problem of obtaining pure cultures of the algae, which to date has not been solved satisfactorily.

The first evident products of photosynthesis are sugars and glycogen, and according to Baumgärtel (1920) these are immediately converted into glycoproteins (cyanophycin granules of Gardner, 1906), which accumulates as stored reserve food in the peripheral cytoplasm. Starch never occurs, but small oil droplets are frequent inclusions, as also are the much disputed "pseudo-vacuoles" in many genera (Brand, 1905; VanGoor, 1925). The blue green algae are generally devoid of true vacuoles and for this reason are able to endure long periods of drought (West and Fritsch, 1927).

Enzyme activity has been studied in various green algae (Hampton and Baas-Becking, 1920; Sjöberg, 1920; Burge and Burge, 1924; etc.), but little is known about the enzymes of Cyanophyceae. Lavelle (1925) found that *Phormidium laminosum* growing in springs at 74°C. produces lipase and a glycogen-splitting enzyme, but neither diastase, invertase, nor casein-splitting enzymes. According to Schmid (1921), *Oscillatoria* produces

an agar-dissolving ferment. An indirect approach to the study of catalytic processes in the activity of *Oscillatoria* has been indicated by Crozier and Stier (1926) in a discussion of the meaning of their thermal increment data. No further data upon the enzymes of blue green algae have been found.

The cell wall in the filamentous Cyanophyceae is regarded as consisting of two investments, an inner somewhat modified plasmatic membrane, and an outer mucilaginous envelope of firmer consistency (Lemmermann, 1910) forming a cylindrical sheath which is continuous (as in *Oscillatoria*) or interrupted between the cells (as in *Anabaena*; Fritsch, 1905). Geitler (1925) holds that all cyanophyceous cell walls consist of pectins, but contain neither chitin nor cellulose. Mameli (1920) has claimed the absence of chitin (cf. also Wester, 1909) and affirmed the presence of cellulose and pectins. Ullrich (1929) has since demonstrated hemi-cellulose together with pectins in the cell walls of *Oscillatoria*.

There is no complete agreement concerning the wall structure, some having claimed it to be net-like (Correns, 1897; Kolkwitz, 1897), others finding it homogeneous (Krenner, 1925; Ullrich, 1926). Many investigators have reported regularly arranged pores in the longitudinal walls of *Oscillatoria* (Kolkwitz, 1897; Phillips, 1904; Schmid, 1921). By using KI and H₂SO₄, Schmid (1921) was able to discover pores in the longitudinal as well as in the cross walls of *O. Jenensis*. However, Ullrich (1926) was unable to discern any pores by employing KI and KOH. That the adjacent cells of the Hormogoniales are connected by plasmodesma extending through pores in the transverse walls (thus unifying the entire filament) has been held by Wille (1883), Borzi (1886), Phillips (1904) and others. West

and Fritsch (1927) suggest that the pores of *Stigonema* can be rendered conspicuous by desiccation and subsequent resoaking in water. Phillips (1904) recommends immersing the material in palladium chloride for a few days to increase the size of the pores. From the literature it is apparent that the visible details of structure depend upon the methods employed in fixation and staining of the material.

One property of the cell walls which appears to be intimately concerned with the movements of these organisms should be emphasized, i.e., their remarkable elasticity. Measurements of the range of elasticity have been made by the plasmolytic method (Brand, 1903), and also stereoscopically under normal culture conditions (Ullrich, 1926, 1929). Species of small diameter have been found capable of the largest percentage of stretching (cf. Hansgirg, 1883; Schmid, 1918).

The secondary cell sheaths not in direct contact with the protoplast are held to be developed either by apposition of new inner layers of mucus (Correns, 1897), by intussusception (Geitler, 1925 a), or commonly by the extrusion of carbohydrate substances through pores in the cell membrane (Kolkwitz, 1897; Schmid, 1921). Fechner (1915) found that by staining with safranin the uneven appearance of the mucilaginous surface in *Oscillatoria* could be made to reveal crossing systems of material arranged at an angle of 35° to the axis of the filament. That secretion takes place in the apical cells only and that the slime gradually moves toward the middle (Fechner, 1915; Gicklhorn, 1921) is denied by Schmid (1921), who claims that secretion occurs along all portions of the filament.

The conditions governing the rate of sheath-formation (which a host of persons have invoked to explain motility) have

to date not received critical attention. Presumably the factors which influence the elaboration of food materials in the plant and the factors which regulate the turgor pressure of the cell and the permeability of its membrane are involved in producing the extruded mucus substances.

The chemical nature of the envelope, which may be extremely thin (*Oscillatoria*) or very thick (*Lyngbya*), varies according to the species. Among the earlier investigators, Gomont (1888) found that



FIG. 3. ILLUSTRATION OF THE VARIABLE NATURE OF THE GELATINOUS SHEATH

- (a) No sheath present in *Oscillatoria formosa*.
 (b) In old cultures the same species is provided with a definite sheath.

although the cell *membrane propre* was insoluble in acids, the sheath was readily soluble and consisted of layers. In an investigation of many genera, Lemaire (1901) concluded that the filamentous Cyanophyceae exhibit three types of sheaths: (1) simple sheaths composed of pectin (*Anabaena*, *Cylindrospermum*, *Gloeotrichia*, *Nodularia*, *Nostoc*), (2) complex type consisting of acid pectins and basic "schizophycose" (*Lyngbya*, *Phormidium*, *Scytonema*, *Stigonema*), (3) mixtures of cel-

lulose and "schizophycose" (*Desmonema*, *Diplocolon*, *Scytonema*, *Tolypothrix*).

Among the later inquiries into the nature of the cyanophycous sheath was that of Klein (1915), who denied that chitin is a constituent as had been reported earlier (cf. Hegler, 1901; Kohl, 1903). Cellulose was demonstrated in the heterocysts and sheaths of *Diclothrix*, *Rivularia*, *Schizothrix*, *Scytonema*, and *Tolypothrix*, but was not found in the sheath of *Lyngbya*. In the sheaths of many genera, pectin was found to be a common constituent, and in *Nostoc* pentosans were found. The thin sheath of *Oscillatoria* (visible in ink suspensions) has not been studied so extensively. Krenner (1925) claimed that hemicellulose, not pectin, forms the isotropic sheath of *O. limosa* (disagreeing with Kohl, 1903, and Fechner, 1915); Ullrich (1929) has reported that (as an artifact) the pectin-hemicellulose sheaths of *Oscillatoria* sp. may be doubly refractive when under pressure.

The sheath (its size, color, etc.) has long been regarded as an important morphological character worthy of the attention of descriptive taxonomists. On the authority of Gomont (1888), the presence of a sheath is the only character which separates the genus *Lyngbya* from the genus *Oscillatoria*. It appears doubtful whether this distinction can in all cases be maintained, based as it is upon a variable character whose quantity at any time must in large measure be dependent upon the factors of the environment. The thickness of the sheath will depend upon the amount of new material which can be excreted by the protoplast upon the internal surface of the older layers of mucus. If a filament be non-motile or subjected to frequent reversal, more mucus can be accumulated about it than in the case of a filament proceeding without reversal at a relatively rapid rate over a long distance

and continually leaving its mucus behind on the substratum (*cf.* Phillips, 1904). Two algae, one answering the description for *O. formosa* and the other for *O. sancta*, were observed recently to have well-developed sheaths in old cultures. When transferred to fresh solutions favorable for the exhibition of translatory movement, the trichomes always glided out leaving the old sheaths behind (*cf.* also Phillips, 1904; Coupin, 1922). This phenomenon is supposed to represent the so-called reproduction by hormogone formation, but is apparently not related to the length of the filaments. It would appear that thickness of the sheath in at least some of the Hormogoniales is a variable quantity which depends as much upon the external environmental factors which influence the synthesis of carbohydrate materials and movement of the organisms as upon internal hereditary factors.

Summarily, it may be said that the Cyanophyceae, characterized by relatively simple cell- and body-structure, very well illustrate "the conception of cell structure which implies differentiated regions of a colloidal system in which special processes have become localized and tend to remain fixed" (Harper, 1919).

THE MECHANISM OF MOVEMENT

Of all the various theories which have been proposed to explain the mechanism of movement in the Cyanophyceae, probably the most popular is that involving the mucus secretions which form the sheath. The secretory mechanism (*cf.* Verworn, 1899) has long been held to be the cause of motility, not only in the blue green algae (Engelmann, 1879; Correns, 1897; Fechner, 1915; Gicklhorn, 1921; etc.) but also in the desmids (Klebs, 1886; Aderhold, 1888; Schröder, 1902) and diatoms (Bütschli, 1892; Lauterborn, 1894,

1896) as well. One point of view would propose that the actual streaming of the outer mucus (plasmic strands), as indicated by the movement of adhering foreign particles, serves to propel the cyanophyceous filament (Siebold, 1849, Schultze, 1865; *cf.* Fechner, 1915) in much the same manner as in the case of diatom frustules (Müller, 1893, 1897; Lauterborn, 1896; Palmer, 1910) and perhaps some amoebae. Engelmann (1879) went so far as to identify the outer mucous material of *Oscillatoria* as a modified plasma membrane, and Schultz had previously held the idea of pseudopodial action in the case of diatom movements. Fechner's (1915) contention that only the apical parts of a filament contribute to movement by secretion of slime was disproved by the experiments of Schmid (1923) with severed portions, in which all parts of a filament were found capable of movement.

In this connection it is significant that streaming inside the cell, as indicated by the motion of cytoplasmic granules under the ultra-microscope, occurs only while the algal filament is in motion (Gaidukov, 1910; Schmid, 1918). That the puzzling movements of diatom frustules may be related definitely to protoplasmic movements has been suggested recently by Dangeard (1931). The inhibitory effect of ultra-violet light upon movement in *Oscillatoria* was attributed to an effect upon the *kontractile Substanz* of the protoplasm by Fuchs (1907). In view of what is known about protoplasmic streaming in such plants as *Elodea*, *Nitella*, etc., it appears not unlikely that the movements of the Cyanophyceae may be related in a definite manner to the activity of the protoplasts, perhaps through the excretion of streaming mucous material.

A somewhat different viewpoint involves the radial swelling of the anisotropic mucus to form a narrow angle which

squeezes the filament forward and away from the smaller end of the sheath (Fechner, 1915; Harder, 1918). This theory might possibly be applied to the cylindrical Oscillatoriaceae, but it would seem difficult to apply to those heterocystic forms in which the mucous sheath is interrupted between the cells (cf. Fritsch, 1905). The anisotropic character of the sheath has been denied by several later workers and the swelling theory stoutly denied by Schmid (1918).

Prell (1921) advanced the hypothesis that movement might be caused by the flowing pressure of gelatinous strands extruded through the numerous spirally arranged pores along the entire length of the filament. These strands of jelly presumably correspond with the position of the pores and are originally separate; final agglutination by swelling results in the characteristic sheath formation. The direction of rotation in screw-like fashion is held to be morphologically fixed by the spiral arrangement of two crossing series of pores; reversal is explained as a response to some external stimulus which checks secretion and causes contraction of the filament. When secretion is resumed, the strands of jelly have a different purchase with respect to the substratum and the filament is caused to move in the opposite direction. This ingenious hypothesis was built upon the work of preceding authors (Fechner, 1915; Schmid, 1918) and has considerable evidence in its favor. In the desmids and the recently described *Ghrootheca mobilis* (Pascher and Petrova, 1931) the pores are sufficiently large so as to extrude quite easily discernible mucous strands which are believed to cause movement; in the Cyanophyceae, however, the optical evidence in support of Prell's hypothesis is not wholly satisfactory. The observations of Phillips (1904), who erroneously concluded from his data that

the extruded protoplasmic strands function as cilia, seem to lend evidence in favor of a secretory mechanism like that proposed by Prell's hypothesis.

The various theories of propulsion by mucilaginous secretions appear less easily applied to the movement of filaments not in direct contact with a solid substratum. Several early workers (Cohn, 1867; Hansgirg, 1883) believed that longitudinal progression took place only while the organisms were in contact with a substratum, but free swimming has since been observed in *Cylindrospermum*, *Oscillatoria*, *Spirulina*, etc. (Nägeli, Pfitzer cited in Vines, 1886; Kolkwitz, 1897; Phillips, 1904; West and Fritsch, 1927). Kolkwitz (1897) noted also the creeping locomotion of *Oscillatoria* on the surface of the water. The author has observed that movement during free suspension in culture solutions, though infrequently encountered, is more rapid than while in contact with a glass surface. To quote Vines (1886): "The creeping movements are suggestive of pseudopodial action but the swimming power would appear to lend support to an osmotic theory."

The osmotic theory of movement has had many proponents in the past, e.g. Borscow, Dippel, Hansgirg, Mereschowsky, Nägeli, etc. (cf. Vines, 1886). Zukal (1880) working with *Spirulina* thought that unequal growth on different sides of the filament would cause distortion of the hydrostatic pressure and hence effect movement. The theory postulated by Hansgirg (1883, 1887) would attribute movement to diosmotic processes resulting from a turgor gradient along the entire filament. When turgor is greater in the cells at one end than at the other, movement continues steadily, but due to an external stimulus (e.g. friction of the foundation) the turgor pressure gradient may be reversed with consequent reversal

in the direction of translatory movement. If the turgor pressure should happen to be equal in the cells throughout the filament, according to the theory, no movement could occur. It is not clear just how suction pressure could be converted into mechanical force sufficient to propel the organism. It should be mentioned here that plasmolytic experiments do indicate differences in the osmotic properties of the cells in different parts of a filament of *Oscillatoria*, for example, but a definite gradient along the axis has not been demonstrated.

Though no good evidence has been offered in favor of the surface tension theory of movement, it is apparent that surface phenomena are intimately con-

method of approach as that of van Honert (1932), who demonstrated the rapid movement of oleate in an ether-water interface, would seem to have the possibility of yielding fruitful results.

Presumably the mechanism of movement in *Oscillatoria* might be similar to that involved in the movement of a small glass tube filled with gum camphor, sealed at one end in a flame and placed lightly upon the surface of water. Under these conditions the glass tube, not unlike *Oscillatoria* in shape, glides rapidly forward in a direction parallel to the long axis and away from the end of lowered surface tension brought about by solution of the camphor. With the aid of a micro-manipulator and fine glass needles, the author has been

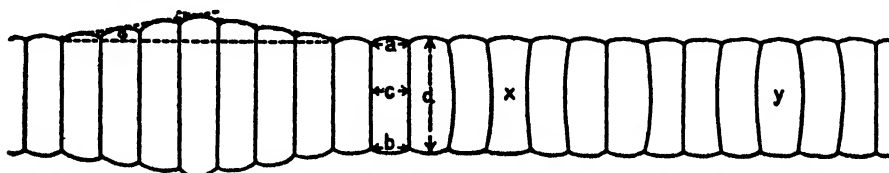


FIG. 4. THE LONGITUDINAL CONTRACTION WAVES IN *OSCILLATORIA* MAY BE INDUCED BY OSMOTIC PROCESSES CAUSING VARIATION IN THE SHAPE OF THE CELLS (CF. *x* AND *y*) AND PERHAPS ALSO IN THEIR VOLUME

Rhythmic changes in the dimensions (*a*, *b*, *c*, and *d*) of the cells throughout a filament have been observed; the magnitude of the transverse wave (measured by the angle α) lies on the border-line of visibility. (After Ullrich, 1926, 1929.)

cerned with the mechanism of movement (cf. Pfeffer, 1906). It is indeed possible that the superficial films of blue green algae, diatoms, crawling euglenas, amoebae, gregarines, etc. are all similarly activated by surface tension changes (cf. Schaeffer, 1917, 1920; Scarth and Lloyd, 1930). Coupin (1923), while observing the movements of *O. limosa*, came to the conclusion that osmotic exchange between the organism and its environment would cause modifications in the surface tension and therefore influence movement. Hansgirg (1883) appears to have been unaware of the importance which might have been attached to a study of the surface tension in his experiments with *Oscillatoria* filaments gliding in almond oil. Some such

able to cut filaments of *Oscillatoria* into two parts and to observe their movement simultaneously under a microscope. The severed portions of filament glide rapidly away from the cut ends where it may be supposed that surface active materials are set free into solution. Furthermore, it has been noted that dried specimens kept in the herbarium for many years will exhibit the characteristic gliding movement when placed in a drop of 10 per cent glycerine in water between a glass microslide and cover. These observations appear highly suggestive and may be interpreted as supporting the surface-tension theory of movement.

Many of the early naturalists were inclined to regard the moving *Oscillariaceae* as

"wurmformig" animals which crawled by peristaltic contractions (Ingenhousz, Purkinje, Dujardin, etc. according to Hansgirg, 1887). Similarly, Cohn (1867) and Migula (1897) believed that movement was in some way brought about through contractility. Rhythmic contractions were noted in *Oscillatoria* by Phillips (1904) and later under dark field illumination by Crozier and Federighi (1924). Brand (1903a) showed that considerable contraction could be produced artificially in *Phormidium* by placing the filaments in hypertonic solutions of glycerine or KNO_3 .

One of the principal champions of the contractility theory in recent years has been G. Schmid (1918, 1921, 1923) who claimed that normal rhythmic contractions of the cells cause the extrusion of the gelatinous stuffs along the entire filament, and also longitudinal and pendulatory movements. These contractions are believed to be set up by osmotic processes which proceed in waves along the filament. By employing solutions of sugar, KNO_3 , NaCl , etc., Schmid found the longitudinal membranes capable of over 30 per cent turgor extension beyond the minimal value.

Careful analyses of the rhythmic contractions in *Beggiatoa* and in *Oscillatoria* have been made by Ullrich (1926, 1929) through the utilization of a stereo-photomicrographic method. In *O. sancta* at 24°C. the velocity of the waves was found to be 13. microns per second, the wave length 25 microns, and the velocity of translatory movement of the filament 0.684 microns, with the waves running against the direction of creeping. As a wave passed through a particular cell in the filament the width of the cell showed an increase and the length a decrease in size, the magnitude of the variations being on the borderline of visibility. In an 8 per

cent sugar solution no waves were observed, yet movement of the filament continued. It was concluded by Ullrich that no definite direct relation existed between the observed waves and the speed of translatory movement.

MOVEMENT IN RELATION TO ENVIRONMENTAL FACTORS

For many years it was hoped to arrive at the truth through abstract reasoning, and the problem of movement in the Cyanophyceae was approached with an attitude of speculation. The newer point of view proposes to build up a theory of the mechanism of movement with the quantitative evidence derived from experiments in which the operating factors are controlled. A brief review of the pertinent data supplied by investigations dealing with movement in relation to different environmental factors will be given in the hope that additional quantitative information may be made available in the future.

Phototactic response in the motile Cyanophyceae was early described by Famintzin (1867), who found that *O. insignis* moved toward light of moderate intensity but turned away from direct sunlight. Bornet and Thuret (1876) noted a light response of hormogones of *Scytonema*; and positive "heliotropism" in *Oscillatoria* was reported by Borzi (1886). That movements of the blue green algae are more rapid in the light than in the dark has been the common belief (Hansgirg, 1883; Phillips, 1904; Pieper, 1913; Harder, 1920). However, Schmid (1921) claimed that light is unessential for the moving mechanism, since he found that *Oscillatoria* kept in the dark for 30 days was capable of movement when transplanted to 1 per cent agar in the dark. The speed of thiobacteria, as also their growth, appears to be independent of the

light intensity (Ruhland and Hoffman, 1925; Crozier and Stier, 1926).

For the growth of blue green algae in inorganic culture solutions proper conditions of illumination are highly important (Harder, 1922; Pringsheim, 1926). A pigmentary response to light of selected wave length and energy content has been claimed to result in complementary chromatic adaptation (cf. Gaidukov, 1903,

of light. Harder (1917 *a*) also has shown that the percentage germination of *Nostoc* spores is proportional to the meter-candle-hours of exposure. The young hormogones of *Nostoc punctiforme* and of *Anabaena variabilis* responded in a positive manner by creeping over the surface of 1 per cent agar toward the source of illumination, and were thus obtained in pure culture by repeated transfers (Harder, 1917). When

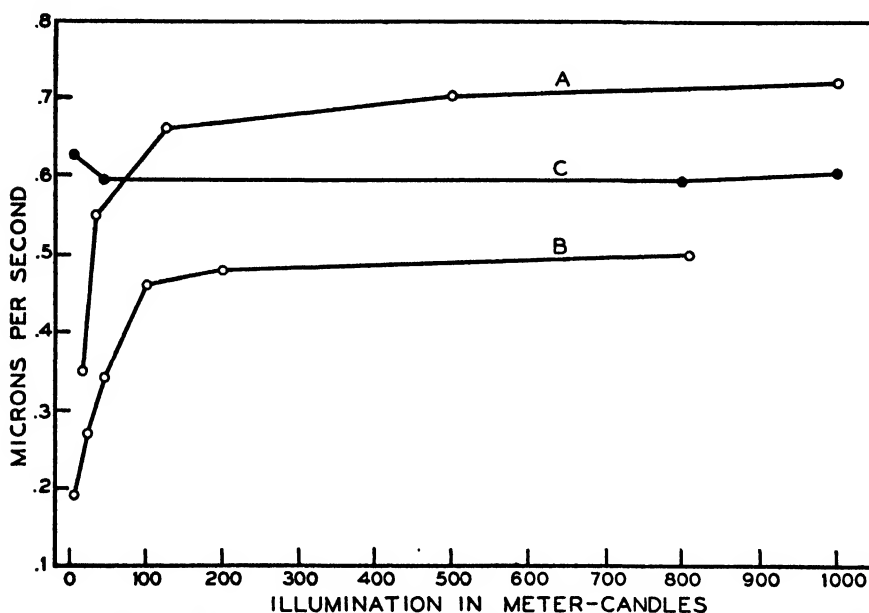


FIG. 5. TRANSLATORY MOVEMENT OF *NOSTOC PUNCTIFORME* UNDER DIFFERENT CONDITIONS OF ILLUMINATION FOLLOWING A PERIOD OF DARK ADAPTATION OF ABOUT 24 HOURS

The primary hormogones (A and B), germinated directly from spores, exhibit a marked acceleration in velocity with increasing light up to about 100 meter-candles; above this region the variation in response is less with change in the illumination. The movement of older hormogones (C) is not influenced much by variations in the light. In A the illumination was varied by the square of the distance; in B the light was modified by employing a rotating sector disc. (After Harder, 1918.)

1906, 1923; Dangeard, 1911; Boresch, 1922). Harder (1923) noted that when *Phormidium faveolarum* was grown under different colored lights, it became chromatically adapted for the highest efficiency of assimilation under the existing conditions. Using equal intensities, he found that a wave length of incident light complementary to the color of the algae afforded better assimilation than did the same color

placed in the shade these algae assumed an heterotrophic existence upon the organic substratum.

The nutritional dependence upon light and the orientation with respect to the direction of the incident light are well-known phenomena in the blue green algae. The mechanism of their phototactic responses is not well understood, though considerable attention has been given to

the problem. Harder (1918) found a variation in the velocity of *Nostoc* filaments when subjected to different light intensities following a 24 hour period of dark adaptation. The speed of the primary hormogones of *Nostoc* increased with the light intensity between 5 and 900 meter candles. Up to 100 meter candles alterations in the intensity produced considerable changes in the rate of progression; above this intensity the effects were small. However, older hormogones were

whether the direction of all incident light was controlled. It is probable that activity might be different under conditions permitting orientation with respect to the

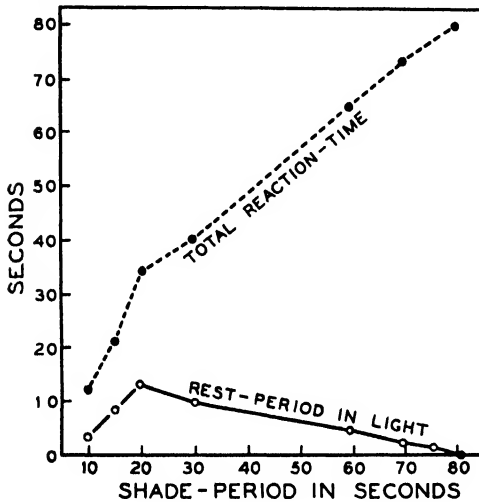


FIG. 6

FIG. 6. THE REACTION TIME (ORDINATE) REQUIRED FOR RESUMPTION OF MOVEMENT IN *NOSTOC* FILAMENTS AFTER QUIESCENCE HAD BEEN INDUCED BY EXPOSURE TO DIM BLUE LIGHT (EQUIVALENT TO DARKNESS ACCORDING TO HARDER, 1920) FOR VARIOUS LENGTHS OF TIME (ABSCISSA)

The filaments were first exposed to bright white light at 200 meter-candles for 2 minutes, then "darkened." When illuminated again with white light, movement was resumed after the lapse of definite periods of time up to 80 seconds. When the shade-period lasted more than a minimum of about 15 seconds, then reversal of direction always occurred, and the length of the rest-period (lower curve) in the succeeding light varied inversely with the duration of the shade-period. The total reaction time, measured from the beginning of the shade-period up to the resumption of movement in the light, appears to be directly related to the length of the shade-period. When the "darkened" period is greater than 80 seconds, movement is resumed upon subsequent illumination without any rest-period in the light. (After Harder, 1920.)

FIG. 7. THE REST-PERIOD IN CREEPING FILAMENTS OF *NOSTOC* IS INVERSELY PROPORTIONAL TO THE INTENSITY OF THE ILLUMINATION DURING A PERIOD OF SHADE

The organisms, accustomed to light of 800 meter-candles, were suddenly exposed to dim light in the range of 20 to 41.5 meter-candles (abscissa) and the time measured for cessation and resumption of movement (ordinate). (After Harder, 1920.)

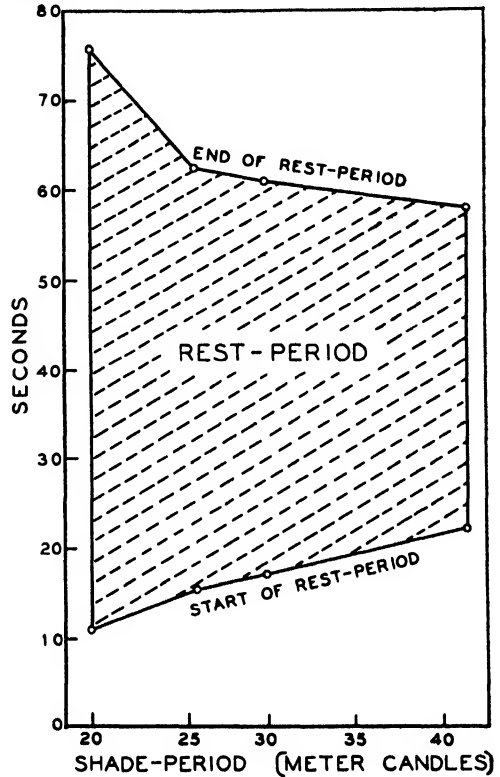


FIG. 7

indifferent to variations in illumination between 5 and 2222 meter candles. It is not clear whether heat effects were entirely eliminated in these experiments and

stimulus, and when such possibilities of orientation are excluded from the experiment.

Significant information as to the mech-

anism of reversal has been given by the same author (Harder, 1920) for *Nostoc* hormogones. Reversal of the direction of movement occurred when the intensity was suddenly lowered; sudden increases in intensity from 0 to 12,000 meter candles gave no reversal. Only when the previous period of illumination had lasted a definite minimum time did a lowering of the intensity result in reversal. The factors concerned were: (a) the period of illumination, (b) the period of shading, (c) the drop in intensity between the two periods. It should be mentioned that other investigations have indicated greater frequency of reversal in short filaments and at higher temperatures (Crozier and Federighi, 1924). Also, the author, has upon occasion observed reversal in dark adapted *Oscillatoria* when subsequently exposed to the light; greater frequency of reversal appeared to be associated with higher light intensity. By no means is the situation clear as to the factors involved in the mechanism of reversal.

The present author was unable to find any significant difference in the velocity of *O. formosa* at different illuminations between 0.01 and 26.2 foot candles after a period of 20 hours of dark adaptation. The temperature was definitely controlled at $22^{\circ} \pm$ a small fraction and the possibility of orientation was excluded from the experiment, since the incident light was perpendicular to the plane in which the organisms were allowed to glide. In other experiments with nine species of *Oscillatoria* it was found that the phototactic sign depends upon the species as well as upon the intensity of light. Negative phototaxis served to segregate *O. splendida* from other positively phototactic species associated with it in the same Petri dish. The diaphototaxis or orientation in such a manner that optimum absorption may be permitted has been

found in the case of *Oscillatoria* filaments exposed to moderate light conditions (Pieper, 1913, 1915). In Figure 8 there is illustrated the autonomous orientation of a culture of *O. formosa*, the filaments being arranged in a position perpendicular to the direction of incident light. Other interesting experiments are in progress with *Oscillatoria* placed in nutrient solution in long glass tubes where the filaments glide spirally upon the inner surface toward suitable light sources.

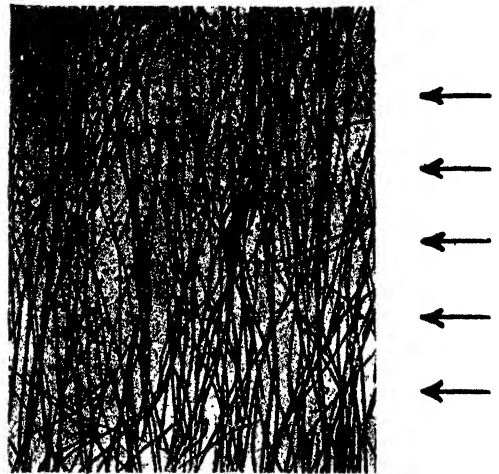


FIG. 8. AUTONOMOUS ORIENTATION OF THE FILAMENTS OF *OSCILLATORIA FORMOSA* IN A POSITION PERPENDICULAR TO THE DIRECTION OF THE INCIDENT LIGHT

Nienburg (1916) employed an ingenious technique for the observation of phototactic response in *Oscillatoria*. A very small beam of light was controlled by different sizes and shapes of apertures and was manipulated so as to illuminate one or both ends or only the middle of a single filament while creeping on a microscope slide. A change from light to darkness always caused reversal; a change from dark to light had no influence upon the direction of movement. Speed was apparently accelerated by increased light intensity (temperature not controlled?).

The conclusion was reached that all parts of a filament are equally reactive to light, but it was not possible to discover whether intensity or "direction of light" was operative in producing the photic responses.

There is certainly some definite relationship between the absorption spectrum of these organisms and their response to light. Absorption of the pigments of several of the members of the Oscillatoriaceae has been studied (*cf.* Engelmann, 1884; Sauvageau, 1908; Boresch, 1921 *a*, 1921 *b*; Wille, 1922), but little effort has been made to correlate movement with light absorption. Schmid (1923) thought that brown species (*O. Jenensis*) with a high proportion of phycoerythrin are negatively phototactic, and green species (*O. Cortiana*) positively phototactic. This assumption cannot be generally applied. Working with *O. formosa*, Pieper (1913, 1915) found positive phototaxis in white light of moderate intensity and negative phototaxis in strong tantalum-light and sunlight. In red and yellow light, at all intensities employed, there was strong positive response; within a definite optimum zone the filaments were oriented at right angles to the direction of the light. In dim green light the response was positive, but under increased intensity it became negative. The blue part of the spectrum seemed to cause a negative response. Pieper concluded that the manner of orientation depended upon the wave length, intensity, and direction of the beam of light.

Since the velocity of physical and chemical reactions bears a definite relation to change in temperature, the rate of biological processes in relation to temperature has been investigated by numerous workers in order to ascertain the nature of the mechanism involved. Harder (1918) studied the rate of linear trans-

latory movement of *Nostoc* in relation to temperature and found the temperature coefficient to be $Q_{10} = 2$ at ordinary temperatures up to 30°C. The temperature coefficient for movement of *Oscillatoria* between 10 and 30°C. was also found by Schmid (1918) to illustrate the Van't Hoff Principle for chemical reactions.

In view of the fact that the temperature coefficient was deemed imperfect for the characterization of the processes concerned in this type of movement (as well as for other biological phenomena), Crozier and Federighi (1924) studied the critical thermal increment (temperature characteristic) of the movement of *Oscillatoria*. The velocity of translation was found to be controlled by the temperature (6 to 36°C.) in accordance with the equation of Arrhenius for irreversible chemical reactions. The value of the critical increment, μ , in this equation,

$$\frac{\text{velocity at } T_2}{\text{velocity at } T_1} = e^{\mu/2 \left(\frac{1}{T_1} - \frac{1}{T_2} \right)}$$

was found to be 9,240. To quote these authors: "The velocity of movement is therefore regarded as determined by the velocity of an underlying chemical process, controlled by the temperature and by the amount of a substance (? catalyst) whose effective quantity at any moment varies within definite limits in different filaments of the alga." In view of a suspected connection between protoplasmic streaming and the movements of *Oscillatoria*, a comparison of the thermal increments for cyclosis in aquatic plants, and of the amoeboid movements of human neutrophilic leucocytes was made with the temperature characteristic for locomotion of *Oscillatoria*. It was concluded that these "are all influenced in a not very dissimilar way by the temperature, although the actual values of the several critical thermal increments seem distinct

and characteristic." Crozier and Stier (1926) studied the temperature characteristics for the speed of movement in *Beggiatoa* and *Thiothrix* and found that above 16.5°C. the value of μ for the former is 8,400 and for the latter 8,300. Below

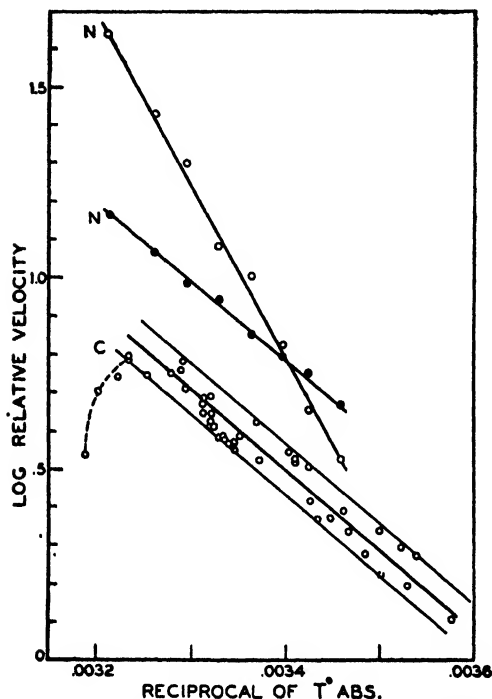


FIG. 9. THE VELOCITY OF TRANSLATORY MOVEMENT OF *OSCILLATORIA* IS CONTROLLED BY THE TEMPERATURE IN ACCORDANCE WITH THE EQUATION OF ARRHENIUS FOR IRREVERSIBLE CHEMICAL REACTIONS

The data indicated by C are taken from Crozier and Federighi (1924). Note that the extreme variates fall within lines parallel to that representing the slope of the set of values. At high temperatures (above 36°C.) the controlling mechanism appears to be disrupted, as indicated by the points breaking away from the characteristic slope. The other plots (N) are taken from the paper by Navez (1928).

this temperature (*i.e.*, 16.5–5°C.) *Beggiatoa* yielded a μ of 16,100, which indicated a different controlling influence in the lower temperature range. It is apparent that the visibly similar phenomena of motility in the blue green algae and the thiothrix may be controlled by similar

underlying chemical and physical processes.

The results of some work upon the movement of *O. chalybea* in relation to the temperature were published later by Navez (1928). What may have been two "temporary physiological races" yielded thermal increments (μ) of 9,450 between 8.2 and 26.2°C., and 21,700 between 13 and 35°C. respectively. The former value is significantly close to that obtained for another species of *Oscillatoria* by Crozier and Federighi. The values of μ about 20,000 are possibly concerned with hydrolytic reactions or processes H^+ catalysed; those below 10,000 might be connected with diffusion phenomena and surface action. Though it has not been possible as yet to identify the process controlling locomotion, it appears quite significant that this type of biological activity has been found to obey the law of temperature influence upon irreversible chemical reactions.

However popular in modern physiological research, the effect of dissolved substances upon cell permeability and the vital processes has not received much attention with respect to the Cyanophyceae. On the other hand, a great deal of attention has been given to this aspect of the problem in other organisms, such as amoebae, infusorians, leucocytes, etc. (Dale, 1913; Pantin, 1923, 1925–26; Fenn, 1922; Chambers and Reznikoff, 1926; Chase and Glaser, 1930). Information concerning movement in other organisms serves to throw considerable light upon, and is in certain instances perhaps directly applicable to the situation in the blue green algae. Further discussion of specific analogies must, however, be deferred at this time.

The osmotic properties and the permeability of several species of *Oscillatoria* have been studied, though no large body

of facts is available on the subject. Brand (1903) has pointed out that plasmolysis does not easily happen in this group, presumably because of the absence of vacuoles, and due to the elasticity of the cell membranes (*cf.* West and Fritsch, 1927). Prat (1921, 1925) found that the isosmotic concentration varied in different species between the limits of 0.8 to 1.5 per cent NaCl and 10 to 13 per cent saccharose. Species of *Oscillatoria* were plasmolysed in

ment was more rapid in relatively dilute Knop's and in relatively concentrated NaCl and saccharose solutions. Schmid (1923) found that the osmotic pressure in the cells of *O. Jenensis* was lower than in other plants for which data were available with the exception of slime molds. According to Prat recovery from plasmolysis was more rapid in the case of monovalent metals than divalent (using the chlorides in all cases). No deplasmolysis with

TABLE 1

The Relative Rates of Deplasmolysis of Oscillatoria in Various Salt Solutions as an Indicator of the Permeability. (0 = Recovery in 30 Seconds to 5 Minutes. + = Deplasmolysis in Concentrations Below M/3 in 10 to 30 Minutes, and in Higher Concentrations from 30 to 50 Minutes. ++ = More than One Hour Required.) (After Prat, 1921)

CATIONS ANIONS	Li	K	Na	Mg	Ca	Sr	Ba
Cl.....	+	o	+	++	++	++	++
NO ₃		+			++	+	+
SO ₄		+	+++	++++			
H ₂ PO ₄		+					
HPO ₄		o					
PO ₄		+					
CNS.....		oo					

TABLE 2

The Relation of Velocity of Movement to Turgor Pressure and Diameter of the Filaments in Several Species of Oscillatoria (after Krenner, 1925)

SPECIES	SIZE	SPEED	MOVEMENT IN SUCROSE SOL.	MOVEMENT INHIBITED	ISOTONIC SUCROSE SOL.	TURGOR IN ATMOS- PHERES
<i>O. Frohlichii</i>	broad	slow	5-6.5%	8.0%	24.0%	16.63
<i>O. curviceps</i>	medium	slow	6-8.5%	9.0%	28.0%	19.40
<i>O. tenuis</i>	narrow	fast	17%	20.0%	37.5%	25.98

1.6 to 1.8 per cent KNO₃ and in 1.0 to 1.1 per cent NaCl. When the concentration of a saccharose solution was slowly increased by evaporation, the immersed algae were able to withstand much higher values than under ordinary conditions. The threshold concentration permitting movement in the species of *Oscillatoria* studied by Prat was 1.5 per cent Knop's solution, 1 per cent NaCl, and 13 per cent saccharose. Below the threshold, move-

MgSO₄ or sugar was obtained, indicating impermeability of the cell membrane to these substances.

Since the manner of movement in the thiobacteria is not unlike that in the Cyanophyceae, the recent investigations of Ruhland and Hoffman (1925) and Ruhland, Ullrich and Yamaha (1932) upon the permeability of *Beggiatoa mirabilis* are of interest in this connection. These authors have concluded from plasmolytic

experiments with a long list of substances that penetration of large organic anions is inversely proportional to the radius of the ion, which lends support to the concept of an ultra-filter mechanism for the permeability.

Attempts have also been made by several writers to correlate speed with the osmotic pressure and size of the filaments. According to Correns (1897) the velocity is proportional to the diameter (with some exceptions). Recently Krenner (1925) has reported that the narrow and rapidly moving filaments of *O. tenuis* have an osmotic pressure of 25.9 atmospheres (using cane sugar); the broad and less rapid filaments of *O. curviceps* and *O. Froblichii* have a pressure of 19.1 and 16.6 atmospheres respectively. The conclusion was therefore put forth that velocity of translation is proportional to the osmotic pressure of the alga, and varies inversely with the diameter of the filament. Whether or not this statement will hold true, the evidence is quite convincing that the greater the osmotic pressure within the cells, the higher the concentration of solution in which the organisms can continue to move.

It is worthy of note that no relation exists between length of filament and velocity of motion (Crozier and Federighi, 1924; Castle, 1926), though there has been a suggestion of some correlation between length and frequency of reversal. Krenner (1925) claims that there is a minimum length below which movement does not occur in each species. Thin species (*O. natans*, *O. tenuis*, *O. tenerrima*) with relatively high osmotic pressure are held to be capable of movement if more than 16-21 cells comprise the filament; in larger species (*O. princeps*, *O. Froblichii*) with lower osmotic pressure, a minimum of from 45-50 cells is required to permit movement. In the thiobacteria, the larger individuals were observed to move

faster than the small ones (Crozier and Stier, 1926). It was suggested by these authors that some relation may exist between velocity and the surface/volume ratio in all these cases.

Nutritive conditions appear to affect both growth and movement by a direct influence upon the elaboration of food materials and upon the preservation of equilibrium in the vital structures of the cell. The long forgotten opinion of Wolle (1887) that growth and movement in the Cyanophyceae are identical is of course not strictly true, though the two are inti-

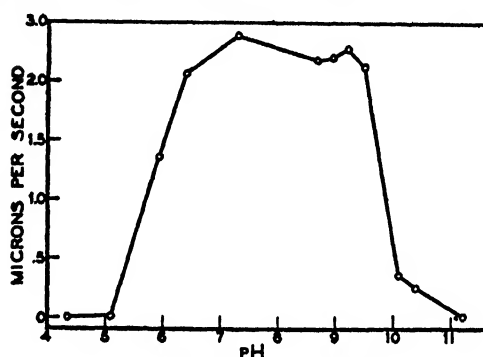


FIG. 10. MEAN RATES OF TRANSLATORY MOVEMENT OF *OSCILLATORIA FORMOSA* AFTER IMMERSION FOR ABOUT 10 HOURS IN CULTURE SOLUTIONS OF DIFFERENT pH

Each point represents the mean value for 10 filaments; all data are taken from a single series representing a typical experiment. Movement appears to be sustained in the region pH 6.4 to 9.5.

mately interrelated. In an investigation of the optimum culture conditions for blue green algae, Maertens (1914) found that properly balanced proportions and concentrations of dissolved salts and a slightly alkaline reaction are required. Directions for the preparation of culture media suitable for the growth of Cyanophyceae may be found in the papers of Pringsheim (1913, 1926), Maertens (1914), and Kufferath (1929). Statements in the literature concerning the deleterious effect of an acid environment appear to be correct, a negative "chemotactic" response to acids hav-

ing been observed by Fechner (1915) and the lethal effect of acids having been noted by Schmid (1923). In recent experiments with *O. formosa*, movement was found to be sustained in inorganic culture solutions within the range pH 6.4-9.5; above and below these limits inhibition of motion was marked (Burkholder, 1933).

Many other phases of the subject remain practically untouched. For example, the analysis of movement under various conditions of O_2 - and CO_2 -tension; the effect of salts, and antagonism; orientation to light in relation to the absorption spectrum; the effect of organic nutrients; etc. Celakowski (1898) reported movement of *Oscillatoria* in the absence of free oxygen and it has been suggested by Coupin (1922) that moisture and the oxygen tension are of great importance but, as in the case of so many other factors bearing upon this problem, no quantitative data are as yet available. The author has found that movement in the light is enhanced by the presence of bicarbonates in solution, and that the phenomenon of antagonism is demonstrated by differential movement of *Oscillatoria* in single and mixed salt solutions ($NaCl$ and $CaCl_2$) of proper concentration. Furthermore, the addition of small amounts of glucose to inorganic culture solutions was found to exert a positive effect upon the movement of *Oscillatoria* which had been kept continuously in the dark for several days.

In controlled experiments, Schmid (1921a) claimed that *Oscillatoria* exhibits neither hydrotropism, stereotropism, nor geotropism. The absence of geotropic response had been reported earlier by Stahl (1884). The interesting behavior of cyanophyceous colonies as units has been commented upon by several authors. For example, Prat (1925) found that the individual filaments tended to aggregate in lower concentrations of salts; in moderately concentrated solutions the filaments

glided about separately. The experiments of Funk (1920) with colonies of *Oscillatoria* in glass tubes showed that the filaments gather closely together at low temperatures or while under the influence of an electric current. Also the individuals tend to scatter in the light and cluster together in the dark. Slight mechanical agitation is known to stimulate a more rapid rate of movement but if carried too far will depress activity of the organisms (Crozier and Federighi, 1924; Schmid, 1918).

SUMMARY

In the filamentous blue green algae, three types of movement have been recognized: linear translation, axial rotation, and oscillation. Linear translation appears to be particularly well suited for study in relation to controlled variables which influence the direction and velocity of movement. Different authors have at various times ascribed the mechanism of movement to growth, the presence of cilia, osmotic currents, the excretion of gelatinous materials, modifications of the surface tension, and peristaltic contractility of the cells. Among the various species of *Oscillatoria* the rate of linear progression appears to be related to the osmotic pressure of the cells and the diameter of the filaments. Other conditions being favorable, the intensity and wave-length of the incident radiation are important in determining the direction and perhaps also the speed of movement. Furthermore, the velocity of linear translation has been found to illustrate the Arrhenius law of temperature influence upon chemical reactions. Numerous investigations of movement in relation to different factors have provided interesting data, but as yet no satisfactory explanation of the mechanism has been offered. The history and present status of the problem have been reviewed in the hope that additional information may be made available in the future.

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MICROBIOLOGICAL ACTIVITIES AT LOW TEMPERATURES WITH PARTICULAR REFERENCE TO MARINE BACTERIA

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ALTHOUGH it is frequently stated in the popular as well as in some scientific literature that the ocean floor beyond the continental shelves is barren of bacterial life, primarily due to the lack of food and the prevailing low temperature and high hydrostatic pressure, investigators have almost invariably demonstrated the presence of an abundant bacterial flora in bottom deposits wherever critical analytical procedures have been applied. In fact, there are usually from ten to ten thousand times as many viable bacteria per gram of mud as there are in a corresponding quantity of water in any superimposed strata. While nearly all of the studies on marine bacteria to date have been made in relatively shallow water near land, a few workers have recovered significant numbers of living microorganisms from mud collected at depths of a mile or more. However, the recovery of organisms from such depths is by no means incontrovertible proof that these organisms are biochemically active in such an environment, because they may be merely passive inhabitants which have settled from above and have been preserved by the cold.

Inasmuch as over four-fifths of the ocean floor exceeds one mile in depth and has a temperature colder than 3°C., it is of importance to know if bacteria and kindred microorganisms survive and if they are physiologically functional under such con-

ditions. Our knowledge of the activities of bacteria in the sea is very fragmentary, but the few investigations which have been made indicate that bacteria probably play an important rôle in the sea. They themselves are consumed as food by many small marine animals and, also, by their activities they produce plant nutrients. They are the responsible agents for many of the chemical and physico-chemical changes which occur in sea water or on the ocean bottom, and they may be of geological importance (cf. Bavendamm, 1932; Benecke, 1933; Waksman, 1934).

Experimental evidence indicates that for practical purposes the hydrostatic pressure of deep water is not inimical to microbial well-being. Tremendous pressures are encountered on the sea bottom but bacteria have been shown to tolerate far greater pressures than occur even in the most abyssal depths. Chlopin and Tammann (1903) found that pressures up to about 2900 atmospheres, or approximately three times that found in the ocean, failed to harm bacteria, yeasts or molds, although individual organisms differed greatly in their susceptibilities to higher pressures. In the experiments of Larsen, Hartzell, and Diehl (1918), non-spore-formers survived at 3000 to 6000 atmospheres and then, at these pressures, compressed gases, such as carbon dioxide, or the sudden release of pressure were found to be more detrimental than pressure itself. The actual recovery of bacteria by Certes

(1884), and recently by Carey and Waksman (1934), from depths near 5000 meters proves that neither the pressure encountered (approximately 500 atmospheres) nor its release, effected by bringing the mud samples to the surface, injures the viability of the microbes.

BACTERIAL RESISTANCE TO COLD

While modern methods of food preservation are based upon the principle that refrigeration prevents or materially retards microbiological activity, it has been recognized for a long time that sub-zero temperatures do not necessarily kill bacteria. According to evidence reviewed by Hampil (1932) *Eberthella typhi* survived -153° , and *Vibrio cholerae* survived -183°C , for 7 days; *Corynebacterium diphtheriae* survived -190°C for 10 days, and *Gonococcus* lived after 24 hours at -195°C . As a general rule, water and soil microbes are more cold-tolerant than these delicate pathogens. In the opinion of Keith (1913) freezing does not harm bacteria unless they are mechanically injured by ice crystals, but on the contrary low temperatures actually favor bacterial longevity by diminishing destructive metabolism. In fact, recent work indicates that in the case of at least certain bacteria, life may linger until absolute zero (-273°C) is reached, since some are unharmed by cooling to -252° , the temperature of liquid hydrogen.

McLean (1918) has described four species of bacteria which he isolated from the ice, snow, and frozen algae of Antarctica in locations where possibilities of air-borne contamination are most remote. Here the mean annual temperature is about -20°C , and temperatures as low as -60° are not uncommon. He believes that some bacteria actually prefer to grow in ice where they learn to live within the liquid sludge of cryohydrates which cir-

culates between the crystals of ice. Issatchenko (1914) has reported finding a rich, varied, and vigorously active bacterial flora in the glacial Arctic. At the present time Paul A. Siple, biologist of the Byrd Antarctic Expedition II, is making observations on the distribution of bacteria in the air, ice, water, mud and animal life of the South Polar regions.

BACTERIAL GROWTH AT LOW TEMPERATURES

Granting that bacteria are not killed by cold, to what extent are they functional at the near-zero temperatures typical of oceanic abysses? While investigating the effects of storage on the multiplication of bacteria in water samples, Ellison, Hackler and Buice (1932) observed that bacteria continue to multiply in iced samples. Similar studies conducted by ZoBell and Feltham (1934) showed that samples of sea water held at near 0°C for a few hours exhibited an increase in the total number of bacteria present, although there was a decrease in the number of predominating species, probably due to the selective action of the colder temperatures. The same investigators later noted a twofold increase in the bacterial population of mud samples after storage at near 0°C for three weeks. Fischer (1888) described fourteen different species of bacteria from water and soil of Kiel harbor which were capable of growing at 0°C . Conn (1914) has shown that, while many factors are involved in the increased bacterial counts of frozen soil, the facts indicate an actual growth of the bacteria therein.

Further evidence of the multiplication of bacteria at low temperatures is furnished by Damon and Leiter (1927) who point out that there is a real danger of human intoxication from certain members of the *Salmonella* group which can multiply in frozen foods. The literature

is replete with accounts of bacteria which grow in foodstuffs at temperatures ranging from a few degrees below zero to a few degrees above. Although milk at 0°C is a mass of floating ice crystals Pennington (1908) noted that bacteria continue to reproduce extensively in the serum. Prescott, Hale and White (1931) have reported that the disagreeable odors and slimy coatings on beef in cold storage are produced by microorganisms which grow readily at temperatures only slightly above the freezing point. Redfort (1932) observed the multiplication of bacteria on fish stored at -11°C after 16 months.

When long periods of time are required before multiplication starts, adaptation of the bacteria to the lower temperatures may be taking place. Such acclimatization to temperatures assumed to be inhibitive has been reported by Prescott and Bates (1931). According to Kluyver and Baars (1932) most bacteria in nature are "pluripotent" or readily adaptable to unfavorable environmental conditions. As one example they mention *Vibrio thermodesulfuricans* (Elion) which is normally characterized by its thermophilic (50°-60°C) requirements but which can be easily acclimatized to much colder temperatures and in so doing becomes indistinguishable from *V. desulfuricans* (Beijerinck). Another manifestation of adaptation is recorded by Waksman (1929) who quotes Mischustin as showing that bacteria isolated from soils of colder climates are capable of growing at lower temperatures than those from warmer climates.

In their excellent contribution to the question of the minimum temperature for bacterial multiplication, Horowitz-Wlassowa and Grinberg (1933) concluded that the number of microbes which will reproduce at -4° to -7°C is appreciable. They examined about 75 organisms including many common bacilli, cocci,

yeasts and molds, most of which they found would grow at 0° to -7°C. In some cases it required as long as 136 days for growth to become perceptible, although a few microorganisms exhibited good growth in a week at -3° to -7°C.

Many marine bacteria have been described which continue to be active at sub-zero temperatures. Forster (1887) isolated a photogenic species from luminescent fish which reproduced at 0°C, and later (1892) he found that bacteria which will grow at low temperatures are quite widely distributed in water and soil. Zirpolo (1929) who has extensively studied the physiology of bioluminescence found that *Pseudomonas pierantonii* grew readily at -4°C although the optimum temperature for multiplication and light production was around 33°C. This bacterium was not killed nor was luminescence prevented at a temperature of -192°C produced with liquid air.

In Bedford's (1933a) comprehensive investigations on the temperature range of growth of marine bacteria, all except six of the 71 different species which he examined grew at 0°C or below in 136 days, after which time the experiment was terminated. Ten of the bacteria had multiplied at -7.5° and 12 others at -5°C. Lower temperatures were tried but not successfully because at -10° the frozen media crystallized to such an extent that results were obliterated.

While no efforts have yet been made at the Scripps Institution to ascertain the lowest temperature at which multiplication occurs, work in our laboratory shows that the majority of the bacteria isolated from the sea reproduce freely at 0° to -4°C. A total of 88 different species of marine bacteria isolated from bottom deposits or sea water have been observed, and all except 12 of them have shown evidence of growth after three months'

incubation at this temperature. Some of them, one the etiological agent of a fish disease (Wells and ZoBell, 1934), produce a perceptible turbidity in appropriate sea water broth after 7 days at -2°C . In another series of experiments on mud samples collected at a depth of 1300 meters where the temperature was 6°C , similar dilutions were plated on nutrient agar and incubated at temperatures ranging from -4° to 25°C . After 4 days' incubation the average count for those held at 25° was 49,000 bacteria per gram of mud, 41,000 for those held at 18° , and those at -4° showed no macroscopically visible colonies. At the end of a week counts on the 25° series became unreliable due to merging of rapidly growing colonies, the 18° series had increased to an average of 46,000, and the -4° series showed 8,000 colonies per gram of mud. The -4° series gave an average count in two weeks of 22,000 and in four weeks of 29,000 while, the colonies were slowly increasing in size and in pigment intensity.

The evidence seems conclusive that a large proportion of the bacteria isolated from the sea can grow at the lowest temperatures found in the depths of the ocean. Furthermore, most marine bacteria are more or less eurythermic, or capable of growing over a broad range of temperatures (from approximately 30° down to such a temperature that the physical constitution of the substrata becomes unfit for their continued metabolism). The majority of the marine bacteria observed by Bedford (1933a) had a temperature range of growth from -5° to 30° or 37°C . It is of interest to note that for most marine bacteria on which information is available their optimum temperature is very near their maximum, and considerably higher than their minimum. For non-spore-formers the lethal temperature is only a few degrees higher than the

maximum at which they grow. This is illustrated by *Achromobacter ichthyodermis* described by Wells and ZoBell (1934) which, following primary isolation, grows at -2°C or perhaps lower; its optimum is about 25° ; its maximum 30° ; and 32° is lethal.

BIOCHEMICAL ACTIVITIES OF BACTERIA AT LOW TEMPERATURES

Although many bacteria reproduce freely at sub-zero temperatures, in the experience of Horowitz-Wlassowa and Grinberg (1933) demonstrable biochemical activities are at a low ebb and the psychrophiles are very feebly proteolytic and lipolytic at temperatures below 0°C . Unfortunately, there is little information available on the minimum temperatures for enzymatic activity. However, it is quite probable that, in general, enzyme action is not entirely suspended until all interstitial water is removed by its solidification due to freezing. The work of Talyract (1901), Glage (1901), and many others proves that proteolytic enzymes elaborated by bacteria are definitely functional at sub-zero temperatures, in some cases as cold as -9°C , as manifested by the spoilage of refrigerated foodstuffs. Sanborn (1930) has described several marine bacteria responsible for the decomposition of fish in cold storage, some of which vigorously continue their proteolytic activities at -5°C . It was the opinion of Browne (1917) that autolysis rather than bacterial action plays the most important part in the initial stage of fish decomposition during storage in ice but, regardless of the source of the enzyme, proteolysis was relatively rapid near 0°C . Bedford (1933b) has shown that the decomposition and red discoloration of refrigerated halibut is due to marine chromogenic bacteria which are functional at 0° to -5°C and perhaps at lower tem-

peratures. Evidence is recorded by Rubentschik (1925) of bacteria from the Odessa limans which multiply freely, liquefy gelatin and form ammonia at temperatures ranging from -2° to 0°C . He described two new species, *Urosarcina psychrocarctica* and *Urobacillus psychrocarcticus*, which split urea at -1.25° to -2.50°C . Berry (1934) has noted the multiplication of yeasts and their fermentation of sugars at -2.2°C .

During the last year the writer has observed several types of biochemical processes which are activated by marine bacteria incubated at from 0° to -2°C . Among these physiological activities may be mentioned the liberation of ammonia from peptones, the decomposition of urea, the liquefaction of gelatin, the fermentation of glucose, the hydrolysis of starch, and the oxidation of ammonium to nitrites. The latter reaction required 27 weeks before it became certain that nitrification was occurring, although large inocula of active nitrifiers were used. In general, the endothermic nitrogenous reactions are comparatively slower at the low temperatures than are the exothermic hydrolytic processes. While in all cases the speed of the reactions is extremely slow, there is an obvious acceleration after the first few weeks of incubation, probably due to adaptation of the bacteria to the cold.

In view of the foregoing information it seems both safe and logical to assume that, as far as the temperature is concerned, bacteria can multiply and activate biochemical changes in the coldest waters of the ocean. Many species of marine bacteria have been found to be active at temperatures even colder than the freezing point of sea water (-1.9° at a salinity of 35 per thousand). Microbiological activity may be quite appreciable on the ocean floor because the temperature of a

large proportion of the latter ranges from 2° to 3°C ., several degrees warmer than the known temperature at which many bacteria have been shown to be functional. While the action of bacteria may be very slow at near-zero or sub-zero temperatures, the total results may be of vast significance in the ocean because of the almost unlimited time and the relative slowness of other processes which are taking place concurrently. For example, the rates of many geological processes are far too slow to be measurable, but the accrued results from thousands or millions of years' activity are stupendous. Furthermore, in the case of the bacteria it is possible and quite probable that those which inhabit the abyssal depths have adjusted themselves so that they are far more efficient than they seem to be under artificial laboratory conditions. Such adaptation to environmental conditions is more or less universal in the plant as well as the animal kingdoms. However, exact knowledge as to what extent bacteria and related micro-organisms are of importance on the ocean floor must await additional information concerning the nutritional, physico-chemical, and biological conditions which exist there.

Certainly the speculations of some writers that the organic matter which sinks to the deep ocean floor is there permanently preserved from decomposition by bacteria is not tenable with the known facts. It is doubtful if the dead bodies of either plants or animals are acted upon extensively by bacteria before the former are devoured by the scavengers of the sea. It must be recognized, though, that there would be many waste products which are unfit as food for animals, and it is primarily these waste products which, constantly raining from above, must be transformed by bacteria into something useful. Otherwise, there would be a con-

tinual drain on the elements essential to protoplasm which would eventually upset the balance in nature. It is probably on the sea bottom that these waste products are transformed by bacteria into plant

nutrients or converted into bacterial cells which are in turn eaten by animals. Thus, the cycle of life in the sea is maintained in spite of high hydrostatic pressure or low temperatures.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of THE QUARTERLY REVIEW OF BIOLOGY, 1901 East Madison Street, Baltimore, Maryland, U. S. A.

BRIEF NOTICES

EVOLUTION

THIS PROGRESS. *The Tragedy of Evolution.*

By Bernard Acworth. Rich and Cowan, London. 7s.6d. net. $7\frac{1}{2} \times 4\frac{3}{4}$; 334; 1934. Captain Acworth of the British Navy, author of *The Navy and the Next War* and *Navies of To-day and To-morrow*, not liking the present trends in politics, economics, engineering, industry, society, science, religion, or what have you, and attributing these tendencies to the influence of the evolutionary viewpoint, proves to his own satisfaction that evolution never occurred, that God created each species *ad hoc* substantially as described in the book of Genesis.

In his rather cavalier treatment of the geological evidences of evolution his principal authorities are Sedgwick, who died in 1873, and Dawson, who died in 1899. Captain Acworth, with his passion for the Absolute, would no doubt reply that the date when a scientist reaches a conclusion bears no relevance to its truth, that truth is the same yesterday, to-day and forever. But the conclusions of a scientist at any given date must be based on the evidence then available; if new evidence is discovered the old conclusion may have to be changed. The argument from the geological evidence is not merely "that because man appeared after fish he is therefore descended from fish" but that there is a graded series of fossil and living forms from fish to man and that as more and more fossils are discovered the gaps in the series are more and more completely filled. There is of course no question of proving past evolution in the same sense that we

prove the existence of Julius Caesar. But there is an equal lack of historical testimony to special creation. If no one saw the evolution of reptiles into mammals, it is equally true that no one has seen God create a species. The authors of the accounts on which Genesis is based do not claim to have been present at the creation. On the other hand, as Conklin points out in his recent Penrose lecture,

Nearly a score of new species of plants, having all the characteristics of true Linnæan species, have been artificially produced by hybridization or operations under experimental conditions with consequent changes in chromosome numbers and associations. These new species are fertile *inter se*, but are sometimes sterile when crossed with either one or both of the parent species, thus fulfilling the strictest definition of true species as laid down by many systematists.

We have thus definite evidence for experimental production of new species.

Many of Captain Acworth's arguments, such as his repeated statement that Mendel disproved natural selection, are no doubt attributable to misunderstanding of a subject with which he is not familiar. However, in other passages his tone is that of a barrister determined to convince the jury at all costs. We fear that he belongs in the same category as Bishop Wilberforce, "a man of restless and versatile intellect, who, not content with success in his own sphere of activity, plunges into scientific questions, with which he has no real acquaintance, only to obscure them by an aimless rhetoric, and distract the attention of his hearers from the real point at issue by eloquent digressions and skilled appeals to religious prejudice."

THE MEN BEYOND MANKIND. *A Study of the Next Step in Personal and Social Evolution.*

By Fritz Kunz. Rider and Co., London.
5 shillings net. 7½ x 5½; 236; no date.

For a delightful, billowy ride the good ship Evolution takes wings of the lightest philosophical fabric. As it is with theological thinking, the hard won theories of science are spun out and stretched to make a bridge that reaches from the innermost of man to the limits of the imaginable.

The style is straightforward, simple, and sincere, making delightful the clever characterizations of our typical social and mental absurdities. If one were not inclined at times to stop and look for the parting of fact and fancy the excursion would be perfect, for the thesis is that there is no parting and all is unity.

We learn that we are in the fifth phase of human evolution, the intellectual phase, characterized by the accomplishments of the Aryan race. The next, the sixth evolutionary billow of humanity, is destined to come from a fusion of races in America, Australia or New Zealand. If these countries fail by misguided leadership Russia is the reserve selection of nature to fulfill the initiation of the age of intuitive brotherhood. Stupid social and economic systems as typified by our legal and financial organizations, will have been sloughed off, and the leisure gained by the elimination of economic cruelty will allow completion of the arts, scientific knowledge, and theosophy. We venture the corollary that the moiling types of mankind will have long since died out from sheer boredom. The author points out that we can already see a terrible *ennui* affecting many young people who have leisure without intellectual development. We quote: (pp. 215-216).

"The world will then be a place of beauty, filled with people who have a desire to learn, and not a crass democracy where everyone thinks himself theoretically as good as his fellow, and, in fact, just a little better." And again: "There are some seven groups of ductless glands altogether, representing the seven aspects of nature. Hence, all the other worlds are partially focused in the ductless glands, from the higher point of view, if not from the doctor's point of view."

This is partly to say that there are seven phases to human evolution. The seventh

phase is the spiritual realm of free souls and the grandeur of that area has not yet been completely imagined for mankind is only far enough advanced to dimly visualize the sixth area and is still confronted with the task of making that evolve. We are in the so-called trap of free will and cannot refrain from being conscious, so why hinder the progress of the coming epoch when all true knowledge will help toward its timely flowering?



POUR ET CONTRE LE TRANSFORMISME.
Darwin-Vialleton.

By A. Mignon. Masson et Cie, Paris. 50 francs. 9 x 5½; 521; no date (paper).

The title of this book clearly reveals the object of the author: a comparison of Darwin's theory with that of the late Professor Vialleton. The latter in an attempt to base his theory only on paleontologic and embryologic evidence admits an evolution of species but denies transformism. This viewpoint is based essentially on the following considerations: (1) transitional species have not been discovered; *Archaeopteryx* for example, he states, is a bird and nothing but that; (2) the earliest example of some species is organically more complex than the descendants now existing; (3) the homology of certain organs and ontogenesis cannot be associated with phylogenesis. Vialleton's belief is that each species springs forth in some geologic epoch, fully armed like Minerva, to evolve, decline and die. The time of its "birth" and form of evolution is dependent on an unspecified "action intelligente."

The author, in a manner deserving great praise, presents fully the elements of both theories placing well in relief their weaknesses. He proceeds also to level criticism at some neo-Lamarckians and at the geneticists who are advocates of the mutation theory. For him, the theory of the former is a scientific credo based on affirmations, and not facts, the latter have accomplished nothing because so far "la mouche drosophile, pour torturée qu'elle soit, demeure une mouche." Still it is from the laboratories that he hopes for future enlightenment.

A book unreservedly recommended for all those who firmly believe in some theory of evolution.



EARLY FORERUNNERS OF MAN. *A Morphological Study of the Evolutionary Origin of the Primates.*

By W. E. Le Gros Clark. William Wood and Co., Baltimore. \$5.00. 10 x 6½; xvi + 296; 1934.

The author believes that the most profitable method of determining the line of evolution which culminated in man is in studying, in proper perspective, the evolutionary development of the whole group of primates. Thus can be noted the "trends of evolutionary development which became manifested in the early generalized Primates, and by following them up, recognize which particular trends led to the line of evolution which culminated in Man." In this volume will be found a comprehensive survey of the results of studies in comparative anatomy and palaeontology of members of the primate group arranged under such headings as: The evidence of the skull, the evidence of the teeth, the evidence of the brain, etc. There are also sections on the relation of the tree shrews to the primates, and on the distribution in space and time, and evolutionary radiations of the primates. In the latter chapter is emphasized the importance of recognizing the principle of orthogenesis in any philosophical study of the evolution of the human race. The investigator will find this discussion of the early forerunners of man particularly useful in pointing out the gaps where future studies should be made. The book is well illustrated and documented and contains an index.



THE MISSING LINK. *Studies in Genesis.*

By Spencer H. Elliott. Group Publications, London. 2s. 6d. net. 6½ x 4; 143; 1934. The curious thing about the title of this book is that comparatively little is said in the book itself about the Missing Link. The "Genesis" of the subtitle is the first

book of the Old Testament, not the phylogeny of the biologists. For the most part Canon Elliott is concerned with drawing moral and spiritual lessons in the usual clerical manner from the stories of Adam and Eve *et al.* However, in the first chapter he does consider evolution briefly and concludes that mankind has

a twofold origin. On the physical side we may trace back our descent through the various stages of life to the dust of the ground from which we were formed; and we may have to admit that we have kinship with the ape, although we are not descended from him. But we have another pedigree which no ape can share—the human spirit which we trace back to God, Who breathed into mankind that which makes a man a living soul.

This, he considers, is proved by the greater mental endowment of man. "The child of two, counting his toes, has already proved himself to belong to a different order from that of the chimpanzee." Yet the child of two has developed without any discontinuity from the child of two weeks, who certainly shows no higher mental capacity than the chimpanzee. May not phylogenetic mental development have followed a similar continuous course?



THE DINOSAURS. *A Short History of a Great Group of Extinct Reptiles.*

By W. E. Swinton. Thomas Murby and Co., London. 15 shillings net. 8½ x 5½; xii + 233 + 25 plates; 1934.

Probably few Americans outside of the scientific group are aware that the region extending from Colorado and Utah north through Red Deer River and Edmonton areas of Canada has contributed the most important finds as well as the most numerous specimens of dinosaurs. The writer of this book, an authority on dinosaurs, is on the staff of the Natural History Section of the British Museum. He gives to the general reader a well rounded picture of all that exploration and research have contributed concerning these ancient reptiles. Even a chapter on disease is included. The numerous illustrations throughout the volume are well chosen. Each section concludes with a bibliography and in the two appendices are given (a) a list of British dinosaurs including author, hori-

zon, locality, reference and type specimen; and (b) a glossary and notes. There is a detailed index.



THE CONSTRUCTION OF MAN'S FAMILY TREE.

By Sir Arthur Keith. *Watts and Co., London.* 1 shilling net. 7 $\frac{1}{8}$ x 4 $\frac{3}{4}$; vi + 54; 1934.

In this little book Sir Arthur Keith traces the history of the various family trees by which zoologists since Haeckel have reconstructed the ancestry of man. He concludes that in broad outline Haeckel's schematization has been borne out by later discoveries of fossil primates, that the resemblances between man and the great anthropoids are more reasonably explained by the descent of man from a common anthropoid stock than by convergent evolution, and that Klaatsch's theory that the anthropoids are degenerate forms of humanity runs counter to the geological record.



GENETICS

ENVIRONMENT AND GROWTH.

By Barkev S. Sanders. *Warwick and York, Inc., Baltimore.* \$4.00 + postage. 9 x 5 $\frac{1}{2}$; xviii + 375; 1934.

This painstaking study shows, in the author's opinion,

that the deductions of the Pearson School from correlation studies are untenable, not merely in respect of growth but in all other spheres where an attempt has been made to evaluate the contribution of heredity on environment through this methodology without the use of other correctives.

Furthermore the author tells us that:

The present study was therefore undertaken for the sake of a more intensive and extensive analysis of the evidence bearing on the relative contributions of heredity and environment to physical growth and development, and a more rigid determination of the tenability of the deductions from correlation studies. The organized data presented in the subsequent pages do not sustain the claims of extreme hereditarianism, more specifically the deductions of the Pearson School which deny the importance of milieu on ontogenetic traits.

These are strong words, and Professor Pearson is a considerable person, who has collected and analyzed probably more quantitative data pertinent to the problem of nature and nurture than any other person who has ever lived. It is not unreasonable, therefore, to examine the basis upon which rests Dr. Sanders' alleged demolition of the structure so laboriously reared by Pearson and his co-workers over a long span of years. Are new and more pertinent observational data brought into the arena by Dr. Sanders? The answer is no. He has collected no new observations. Has he discovered a new and more potent method of analysis? Again the answer is no.

All that he has done is (1) to criticise the logic of biometric technique (in the first chapter) on grounds and in a manner that we fancy Prof. Pearson could make very fine hash indeed of, if he felt it desirable to take the trouble to do so. (2) To review at length the biological literature (in Chapter 2) that supports the somewhat trite platitude that heredity and environment are inseparable relative to living organisms, each playing a rôle in the determination of every characteristic of every organism. Incidentally we suspect that there lives no biometrician so dumb as not to be aware of this. As might be expected the author finds the idea that acquired characters may be transmitted to the progeny a seductive one. (3) To review at great length an enormous body of literature (in the next five chapters) on the general subject of differential growth in relation to environment. A final chapter sums up the author's conclusions. An indexed bibliography of 65 pages close-set in 8-point type, and a subject index complete the volume.

The book has two merits. The first is the author's insistence, reiterated again and again throughout the book, on the importance of more and more penetrating investigations of the *specific* effects of precisely defined environmental variables upon the human organism, rather than general studies of "heredity *versus* environment." By any technique now conceived of, these latter studies will never *convince* anyone except their protagonists, the boys who did them, on one side or the

other. Dr. Sanders' second significant contribution is his bibliography, and the annotations on it, which is, in effect, what the text of his Part II is. This bibliography will make the book a valuable reference book for a long time to come.

The book is very well produced, and the publisher deserves all praise for undertaking so tremendously expensive an enterprise in times like these.



THE CHANCES OF MORBID INHERITANCE.

Edited by C. P. Blacker. William Wood and Co., Baltimore. \$5.00. 8½ x 5½; xi + 449 + 3 plates + 3 folding charts; 1934.

This symposium on various disease forms which directly or indirectly are supposed or known to be inherited is written especially for the physician faced by the problem of advising his patients on whether they should have children. The diseases discussed are: nervous disorders and epilepsy (W. Russell Brain), mental disorders (A. J. Lewis), mental deficiency (H. Herd), disorders of the eye (Stewart Duke-Elder) and of the ear (E. J. McCann), asthma and other allergic diseases (G. W. Bray), blood (L. J. Wits), cardio-vascular (M. Campbell), renal (A. A. Osman), skin (L. Forman), gastro-intestinal (M. E. Shaw), cretinism and goitre (H. Gardner-Hill), diabetes mellitus and glycosuria (R. D. Lawrence), tuberculosis (E. R. Boland), neoplastic diseases (A. Piney), congenital abnormality of the skeleton (H. A. Harris). Included are also a very good chapter on genetic principles by R. Ruggles Gates and one on the analysis of pedigrees by L. Hogben.

Although not all the subjects have been well treated, some omitting the results of the more recent studies, still it must be said that this represents a very useful contribution. Outstanding and praiseworthy is the fact that the evidence is presented objectively without drawing unwarranted conclusions or attempting to inject eugenics propaganda.

There is a glossary of genetic and psy-

chiatric terms and an index of nine pages. The references are at the end of each chapter.



L'ÉVOLUTION. ADAPTATIONS ET MUTATIONS. *Berceaux et Migrations. Actualités Scientifiques et Industrielles 47. La Paléontologie et les Grands Problèmes de la Biologie Générale.*

By Charles Fraipont and Suzanne Leclercq. Hermann et Cie, Paris. 10 x 6½; 38; 1932 (paper).

ADAPTATIONS ET MUTATIONS. *Position du Problème. Actualités Scientifiques et Industrielles 48. La Paléontologie et les Grands Problèmes de la Biologie Générale.*

By C. Fraipont. Hermann et Cie, Paris. 6 francs. 10 x 6½; 26; 1932 (paper).

These are the first two of a series of five brief monographs by Prof. C. Fraipont and associates in which they discuss different aspects of organic evolution and review the evidence which favors a more or less modified Lamarckism as against the mutation theory.

In the first, the authors summarize Rosa's Ologenesis theory and accept the latter's assertion that each species appears for the first time simultaneously in all parts of the globe where conditions permit its existence. It is only after the species has passed its maturity and is dying that it is gradually restricted to a smaller area. The authors present maps to show the extent of the habitat of different species as it appears from the earlier geologic record and its reduction in later periods or at present. There is no necessity, conclude the authors, to seek a place of origin for the species nor to set up imagined reasons for mass migrations, etc.

In the second, the Lamarckian principle of gradual adaptation is reaffirmed and the author heatedly denies the value of the negative laboratory experiments as proof against the theory.

Is this a true revival of Lamarckism at the hands of paleontologists who have always been partial to it or is it the last flicker of life from old French "die-hards?"

RACING CAPACITY IN THE THOROUGHBREED HORSE. *Part I—The Measure of Racing Capacity. Part II—The Inheritance of Racing Capacity.* Carnegie Institution of Washington, Supplementary Publications No. 7.

By Harry H. Laughlin. Carnegie Institution of Washington, D. C. 50 cents. 9 $\frac{1}{2}$ x 6 $\frac{1}{2}$; 26; 1934 (paper).

Two empirical formulas are discussed; one for determining an index of racing capacity of an individual horse in terms of age, sex, weights carried, distances run, and speeds attained; the other, for determining an index of the most probable racing capacity of an individual horse in terms of the racing capacities of its direct and collateral near-kin. In the derivation of both formulas, as has always been the case in attempts to develop single indexes designed to represent complex functional abilities, it was necessary to assign arbitrary weights for the proportional influence of different variables. Whether or not all of the important variables were considered, and whether or not approximately correct weightings were given, obviously, can be known only after the indexes have been used very extensively. It may be presumed, however, that the really important variables were included and that a reasonably satisfactory weighting or stressing of each has been obtained. Unfortunately the observational data on which the study was based are not included and only the most superficial information is given of the analytical methods used.



EMBRYOLOGY AND GENETICS.

By Thomas H. Morgan. Columbia University Press, New York. \$3.00. 8 $\frac{1}{2}$ x 5 $\frac{1}{2}$; vii + 258; 1934.

Professor Morgan has resorted to several kinds of simplification in order to make his survey of experimental embryology and developmental genetics into a stimulating textbook for college and medical school students and for others in search of an up-to-date and authoritative introduction to these subjects. His aim has been to illustrate the principles underlying development rather than to describe the embryology of individual types in detail, and to make the reader attentive to the

logical implications of the data of observation and experiment. Verbal explanations have been replaced whenever possible by illustrations, and bibliographic references have been omitted from the text. There is a selected bibliography in the back of the book, however, and an index.



GENERAL BIOLOGY

STUDIES OF THE WATERS ON THE CONTINENTAL SHELF, CAPE COD TO CHESAPEAKE BAY. I. The Cycle of Temperature. *Papers in Physical Oceanography and Meteorology, published by the Massachusetts Institute of Technology and Woods Hole Oceanographic Institution, Vol. II, No. 4. Contribution No. 34 from the Woods Hole Oceanographic Institution.*

By Henry B. Bigelow. Woods Hole Oceanographic Institution, Woods Hole, Mass. \$1.00. 11 x 8 $\frac{1}{2}$; 135; 1933 (paper).

This paper is a continuation of studies on the thermal status of the waters over the off-shore part of the continental shelf, begun in 1913 by the U. S. Bureau of Fisheries and Museum of Comparative Zoölogy. Cruises for the collection of temperature readings were made during several months of the year from 1927 to 1932. Results are given in tables and graphically in the form of thermal contour lines on outline maps. The author may be commended for a clear-cut and concise report of basic data of first order importance.



THE TEACHING OF BIOLOGY.

By William E. Cole. D. Appleton-Century Co., New York. \$2.00. 7 $\frac{1}{2}$ x 5; xiv + 252; 1934.

This book deals with the teaching of biology as a unified subject, that being the accepted organization for the secondary school. The treatment is from the immediate viewpoint of the teacher, in simple and interesting language, and the treatment is thoroughly modern in the light of educational theory and practice. Features of practical importance are: The abundance of suggested teaching aids;

equipment, use and arrangement of laboratories; and appendices including a classified bibliography, a list of outstanding magazines of science, addresses of scientific supply houses, and forms for survey blanks for a number of local problems in biology. There is a brief but adequate index. The treatment of the subject as a whole will be especially helpful to anyone interested in the teaching of elementary biology.



PRINCIPLES OF ANIMAL BIOLOGY. Fourth Edition.

By A. Franklin Shull, with the collaboration of George R. Larue and Alexander G. Ruthven. McGraw-Hill Book Co., New York. \$3.50. 9 x 5½; xiv + 400; 1934.

LABORATORY DIRECTIONS IN PRINCIPLES OF ANIMAL BIOLOGY. Fourth Edition.

By A. Franklin Shull, with the collaboration of George R. Larue and Alexander G. Ruthven. McGraw-Hill Book Co., New York. \$1.00. 9 x 5½; ix + 100; 1934.

In the present revision of his well-known college textbook the author has directed his efforts towards a greater simplicity in exposition; but, on the whole there is very little difference between this and the previous editions (cf. this REVIEW, Vol. 5, p. 248).

The same can be said for the Fourth edition of *Laboratory Directions* which serves nicely to teach beginners some practical applications of the fundamental principles of biology.



HUMAN BIOLOGY

FRANKLIN PAINE MALL. *The Story of a Mind.*

By Florence R. Sabin. The Johns Hopkins Press, Baltimore. \$2.75. 8½ x 5½; xiii + 342 + 8 plates; 1934.

Franklin P. Mall was unquestionably one of the leading figures in the scientific world of his time. While always zealously and overtly holding faithful to his first love, medicine, he was more than a medical man. For one thing he was one of the acknowledged leaders of his time in biology, and unquestionably had more to do

than any other one person with changing the status of human anatomy in this country from being the lowly hand maiden of surgery to a branch of general biology. Again he was no less a leader in altering the outlook of American universities relative to the dignity, the methods, and the spirit of the teaching of science.

He has waited a decade and a half for a biographer. But as he himself would say if he could; it paid to wait! For Dr. Sabin's is a masterly piece of biographic writing—a worthy, just, and adequate treatment of a great subject. And it is done with a devotion that plainly must have made the labor a delight. But fine as is this devotion to the master from a pupil now herself a master, it is not that which makes this a notable book. It is rather the fact that Dr. Sabin has, with great shrewdness and good judgment, set Mall's life as the central jewel in the coruscating background of the most brilliant period of equal length in the progress of the medical sciences that history has yet recorded—"the period of Claude Bernard, Virchow, Cohnheim, Hoppe-Seyler, Schmiedeberg, Lister, Helmholtz, Pasteur, Koch, Ludwig, and His—the period of the foundation of new medical sciences—bacteriology, cellular pathology, biological chemistry, and later immunology." Mall's career as a student started as this period was beginning. He was an important figure in it. The theme is clear and Dr. Sabin has done full justice to it. The book is, in short, a contribution of first-rate importance to the history of ideas, and not just another biography.

The first chapter on early life and education shows how inadequate was the training the Middle West had to offer a boy of Mall's capacities in the '60's and '70's. In the autumn of 1883 he went to Germany, *et incipit vita nova*. During the next three years, first with His and then with Ludwig, his research laid the foundation of his enduring reputation. These were very happy years. At their end he came to Baltimore as a fellow in pathology under Welch in the newly opened Johns Hopkins Medical School. There, except for short interludes at Clark and Chicago, he spent the remainder of his days.

Space is lacking to follow in detail the

course of events in a busy life. The book itself must be read, and then one will see with the utmost clarity how and why Mall influenced students, teaching, research, scientific societies, journals, institutes and foundations as he did. We can do our readers no greater service than to urge them to read this book. For it is *their* book, written for biologists, by a biologist, about a great biologist.



NEGRO-WHITE ADJUSTMENT. *An Investigation and Analysis of Methods in the Interracial Movement in the United States. The History, Philosophy, Program, and Techniques of Ten National Interracial Agencies, Methods Discovered Through a Study of Cases, Situations, and Projects in Race Relations.*

By Paul E. Baker. Association Press, New York. \$3.00. 9½ x 6; 271; 1934. This study is based on an investigation of ten national interracial agencies in the United States and was presented as part of the work for the degree of Doctor of Philosophy at Columbia University. The first 47 pages have to do with the methods of investigation and the history, philosophy and program of the interracial agencies. Section III which forms the bulk of the volume is concerned with *A discovery of methods through a study of the activity of interracial agencies in typical situations.* Summing up the results of his study the author finds that

After this extensive review of the facts our conclusion must be that present attempts to solve American interracial problems are characterized by the presence of two distinct goals and two distinct methods of reaching those goals. These goals are at one extreme a definitely bi-racial society and at the other extreme a completely assimilated race, while the general methods used are either those of conference and coöperation or those of pressure and violence.

On the basis of present trends it seems probable that the conference technique will be used increasingly, but that the conflict method will grow in favor until it effects such reorganization of society as will give the Negro equal status and so make possible the use of the conference technique on an equality basis. If this occurs, the assimilative process will progressively eliminate race differences and so make unnecessary any further interracial effort. If it does

not occur, we can envision between the races only continued conflict which palliative methods of adjustment can mitigate but never solve.

The volume concludes with a bibliography and an index.



A CHILD WENT FORTH. *The Autobiography of Dr. Helen MacKnight Doyle.*

By Helen M. Doyle. Gotham House, New York. \$3.00. 8 x 5½; 364; 1934.

Dr. Helen MacKnight Doyle tells vividly her struggles as a pioneer in the practice of medicine. The first part of the book is a personal record of childhood memories of the spacious '80's in California. Grandmother had a lace cap and knew how to make brown gravy. No salad and salted nuts days were those; in fact not until our author was enrolled as one of three women medical students in Toland Hall in old San Francisco did she hear of a salad.

Women were not wanted in the medical schools of those days and were frankly told so, but Helen MacKnight's Scotch stubbornness carried her through her years of study and internship to a practice of her own. There is much of historical interest concerning San Francisco and the Sierra Nevada country but perhaps the most interesting part of the narrative is the struggle for existence of the pioneer women physicians. The first woman student at Toland Hall was told by one of her professors: "A woman has no business to study medicine. If she does, she ought to have her ovaries removed." To this she replied: "If that is true, the men students ought also to have their testicles removed!" As regards the physiological and psychological limitations of women in medicine Dr. Doyle relates that three weeks before her baby was born she attended a woman in confinement and did the same three weeks after. As Mary Austin says in her foreword: "... it is difficult to separate Dr. Nellie's success in a difficult and exacting profession from her success as a woman. And in saying that, one has perhaps stated the final judgment of this whole vexed problem of women in professions."

LA RÉVOLUTION DÉMOGRAPHIQUE. *Études et Essais sur les Problèmes de la Population.*

By Adolphe Landry. Recueil Sirey, Paris.

25 francs. 9 x 5½; 229; 1934 (paper).

The first and larger part of this book (165 pages) contains two long essays on the demographic revolution and depopulation and decadence respectively. The first is a careful, cautious discussion of the falling birth and death rates and the approach to a stable population, with special reference to the consequences in manifold directions of these phenomena, particularly as they apply to France. Nothing very new is developed in the way of results or ideas, but the author has the merits of conservatism and realism. He handles the facts in a scholarly way, and points out with brutal clarity that there is no simple or miraculous solution that can be applied to check or control a tendency towards depopulation once it is well started in any population, and especially in a highly civilized and intelligent one. The second essay discusses the association between depopulation and decadence, chiefly upon the basis of the history of Greece and Rome (the *monde romain*, not Il Duce's home office). Again a scholarly discussion, saturated with pessimism.

What Landry's argument seems to lack is an adequate appreciation of the fact that human biology has been, as yet, but very imperfectly explored; and of no region is this more true than of reproduction. Like Malthus his reasoning and his viewpoint are those of the historiographer and "social scientist" so-called. His pessimism is essentially a mirror image of Malthus's and is quite as likely to be made silly by the unpredicted and still unpredictable course of human reproduction in the mass under the impact of altered circumstances.

The second part of the book reprints four short essays on various aspects of population problems.



BLINDNESS AND THE BLIND IN THE UNITED STATES.

By Harry Best. The Macmillan Co., New

York. \$6.50. 9½ x 6½; xxii + 714; 1934.

An extensive survey which will be found invaluable by social workers and those interested in public health, by legislators, and by physicians. The chief object of the study was to furnish the social economist with a working treatise on a subject which up to the present has been dealt with in a humanitarian rather than in a scientific manner. The blind are regarded as "certain components of the population of the state who demand classification and attention in its machinery of organization." In the seven sections of the survey no important phase of the subject has been neglected. How wide the scope of the book is can best be indicated by picking at random a few of the topics of discussion: Causes of blindness, possibilities of prevention, the blind by sex, by race, by nativity, marital conditions of blind, extent of education among blind, legal treatment, cost, history of education of blind in United States, public and private institutions for the blind, use of raised print, libraries, homes for adult blind and for children, industrial establishments for blind, pensions, indemnity, private associations and public commissions for blind, etc., etc. An enormous amount of statistical data is given; there is a section on conclusions with respect to work for blind, and in a group of five appendices will be found additional tables and illustrations. The volume is indexed.



JAPANESE IN CALIFORNIA. *Based on a Ten per Cent Survey of Japanese in California and Documentary Evidence from Many Sources.* Stanford University Publications, University Series. Education-Psychology, Volume 1, Number 2.

By Edward K. Strong, Jr. Stanford University Press, Stanford University, Calif. \$1.00 (paper); \$1.50 (cloth). 10 x 6½; 188; 1933.

This report, the second in a series of four dealing with Japanese in California, gives extensive data on birthplace, age, sex, size of family, births and deaths, also information on education, occupation and

religious affiliations. The survey, made by twelve people five of whom were of the Japanese race, covered certain definite geographical districts of about 1000 persons each. City, town and country dwellers were represented. Out of a total population in California of 97,456 Japanese, 9,416 (half of whom were children) were personally interviewed. Concerning the birth rate of the first generation in the United States, records show it to be higher than that of the whites, but not as high as frequently has been claimed. The Japanese married man has had about 3.1 children on the average and the Japanese woman 3.3 children. The birthrate of the second generation cannot be estimated for only a handful are old enough to marry but "it would appear that these young people educated in American schools are most likely to imitate their white acquaintances and limit their families very decidedly."

The statistical data are arranged in 68 tables. Included in the report is a section on the distribution of the Japanese in the United States. There is an index.



MATERNAL MORTALITY IN FIFTEEN STATES.
United States Department of Labor, Children's Bureau Publication No. 223.

U. S. Government Printing Office, Washington. 20 cents. 9 $\frac{1}{8}$ x 5 $\frac{1}{8}$; xiv + 234; 1934 (paper).

This report, following the recent publication by the New York Academy of Medicine Committee on Maternal Mortality in New York City in 1930, 1931 and 1932, gives similar data on maternal mortality in 1927 and 1928 for the states Alabama, Kentucky, Maryland, Michigan, Minnesota, Nebraska, New Hampshire, North Dakota, Oregon, Rhode Island, Virginia, Washington, Wisconsin, California and Oklahoma. In both studies, reported cases of puerperal deaths were investigated by trained field personnel, detailed histories of the circumstances of each death were obtained and the data transmitted to their respective committees for analysis. Both committees arrive at much the same general conclusions. It is pointed

out that a very large proportion of maternal deaths are preventable; that there is great need for better training of persons responsible for maternal care; that physicians and their organized medical societies must assume the leadership in the field; that the general public must be given widespread education of the importance of prenatal, natal, and postnatal care, the dangers of abortion, and of their own responsibilities. The Children's Bureau is to be commended for carrying through this extensive and valuable investigation. Special praise should go to Dr. Frances Rothert for her clear-cut analysis and well written report.



THE MYSTERY OF STIGMATA. *From Catherine Emmerich to Theresa Neumann.*

By Jeanne Danemarie. Translated from the French by Warre B. Wells. Burns Oates and Washbourne, London. 5 shillings. 7 $\frac{1}{2}$ x 4 $\frac{1}{2}$; viii + 248; 1934.

A devout and cultured Roman Catholic with a penchant to describe her own mystic feelings writes this book on stigmata in which she sketches the lives of the nineteenth century stigmatized nun, Anne Catherine Emmerich, her official biographer, Clement Brentano, and her spiritual descendant, Theresa Neumann of Konnersreuth whom the author personally visited. It is on her own personal emotions that Mme. Danemarie dwells so that we learn no more about Theresa Neumann than that which has appeared in numerous articles and books (cf. *Konnersreuth*, noticed in Vol. 8, p. 175 of this REVIEW).

Written in a style *sui generis*, this book and the gentle author also might well have been contemporaries of Jacopone da Todi of whom we are reminded by the following words taken from the introduction: "Here is the story of the journey that led me to the Stigmatised Woman of Bavaria, all athrob with the martyrdom of her wounds and the clairvoyance of her ecstasies."

The work of the translator appears to have been well done.

EARLY DAYS AMONG THE CHEYENNE AND ARAPAHOE INDIANS.

By John H. Seger. Edited by Stanley Vestal. University of Oklahoma Press, Norman. \$2.00. 9 x 6; 155; 1934.

This interesting book gives an account of the author's experiences among the Indians in the early years of their life on reservations. Most of the officials of the agency were Quakers, full of the noblest intentions but with little insight into the ways of thought of their Indian charges. They tried to teach the Indians to farm but, quite understandably, the latter preferred the excitement of hunting buffaloes to the drudgery of farming. Seger started as builder and Jack-of-all-trades on the reservation but soon acquired so much prestige among the Indians by his courage and conjuring feats that he was made head of the school for the Indian children. His struggles to maintain discipline among his pupils and their parents, who not infrequently drew a gun or a knife on him, the loyalty of the Indians after he had succeeded in making them his friends, the disputes between the Indians and the white settlers, are all interesting chapters in the history of the relations between the two races. An appendix gives the tribal tradition of the Cheyenne Indians as told to Mr. Seger by one of the chiefs to whom it had been handed down by word of mouth.

**THE PROPLING OF AUSTRALIA. (Further Studies.)**

By K. H. Bailey, J. B. Brigden, H. Burton, D. B. Copeland, F. W. Eggleston, A. S. Kenyon, F. R. E. Mauldon, H. A. Mullett, G. Packer, P. D. Phillips, W. I. Potter, G. Taylor, S. M. Wadham, A. G. Whirlam. Editorial Committee: F. W. Eggleston, P. D. Phillips, G. Packer, E. Scott, S. S. Addison. Melbourne University Press, Melbourne. 6s. 6d. net. 7½ x 4½; 327; 1933.

In this volume we find a continuation of the investigations on the demographic and intercorrelated economic conditions of Australia (cf. Vol. 5, p. 473 of this REVIEW). The present survey gives a summary of the immigration policy both his-

torically and from the standpoint of the state of public opinion towards new immigration; the limitations imposed by the economic conditions of Australia to an increase in population; the apparent immediate effects of state aided settlements. The several authors limit themselves to an exposition of the facts which can be used to support either of the two opposing viewpoints: limited immigration or lowering of the barriers. Each is consistent *per se* depending on the future; i.e., whether Australia will continue to be an exporting nation or must rely entirely on its own market. In regard to the State planning of communities, all agree that the experience so far has been disastrous for the public exchequer.

**CHILD MARRIAGE: The Indian Minotaur. An Object-Lesson from the Past to the Future.**

By Eleanor F. Rathbone. George Allen and Unwin, London. 2s. 5d. net. 7½ x 4½; 138; 1934.

Since 1846 Indian administrators have passed laws tending to curb child marriage so prevalent amongst the natives. These laws have been ineffectual as is known and the author in rather violent manner lays the blame on the English and Indian authorities whom she accuses of fearing the effects of applying such obviously unpopular regulations. The descriptions of the sad state of the Indian woman arouse pity. Early marriage, aside from the grave social burden which it imposes, has as direct evil there the high mortality due to lack of hygienic measures in puerperium. But the author, evidently gifted with a highly developed reform complex, shows lack of political insight in her attack on the already troubled officials, and the short-sightedness common to reformers in her proposed amendments to the latest statutes (Sarda Act). They are three, two of which would permit prosecution by the courts on privately obtained information. In addition, her main method of attack would be to grant greater political franchise to women and arouse then their organized protest. It has apparently not occurred to the author that the fundamental and immediate need is

that of alleviating the hygienic conditions, and that social evolution would follow as a consequence.



KEITH LUCAS.

Contributors: H. H. Turner, F. C. Temple, Sir Walter Fletcher, G. Ll. Hodgkin, E. D. Adrian, Mervyn O'Gorman, Bertram Hopkinson, R. H. Mayo. W. Heffer and Sons, Cambridge. 5 shillings net. 7½ x 5½; 131; 1934.

After the death of Keith Lucas in the World War Sir Walter Fletcher, with whom he had been associated at Cambridge, intended to prepare a memoir of him and, with this end in view, asked several of Lucas' friends to write accounts of those aspects of his life with which Fletcher was not himself familiar. However, other duties interfered and the memoir was never written. The papers are therefore here published in their original form with the addition of an account by Professor Adrian, a pupil and later a colleague of Lucas, of his life at Cambridge and of his pioneer work on the excitation of nerve and muscle which Adrian himself has continued so brilliantly. The chief impressions which the book leaves are of Lucas' personality, the clearness of thinking which enabled him to state his problems in a form which would permit of an answer, and the mechanical skill with which he constructed his experimental apparatus. A list of his scientific writings is given.



SCIENCE, RELIGION AND MAN.

By William J. J. Cornelius. Williams and Norgate, London. 15 shillings net. 8½ x 5½; 387; 1934.

The author's formal definition of God is "the idea of power exercised by a Spiritual Agency." While for the modern man who does not believe in the existence of God "an absorbing intellectual interest" may be his god, "no one can get rid of the necessity of a god." The real nature of God will be revealed. "The adventure we make justifies our action if simply and

honestly made, and if proof does not come to us in this life it is because that is reserved for the time when, purified and fit for the vision by transformation, man shall see God as He is." Religion is not so simple and is finally decided to be "incapable of exact definition."

Included in the volume are chapters on magic and a very much condensed survey of various religions, ancient and modern. There is a bibliography and an index.



INCOME IN THE VARIOUS STATES. *Its Sources and Distribution. 1919, 1920, and 1921.*

By Maurice Leven. Based upon Estimates of the National Totals by Willford I. King. National Bureau of Economic Research, New York. \$3.50. 9 x 6; 306; 1925.

This book gives estimates for the various states in 1919, 1920, and 1921 of current income—including "(1) wages, salaries and pensions, (2) profits withdrawn from business, (3) dividends, interest, and rent received by individuals, (4) the rental value of homes occupied by their owners, (5) interest upon the sums invested in household furnishings, clothing, and the like, and (6) the value of commodities which families produce for their own consumption"—and gains or losses in the value of property owned. The per capita current income of the Southern states is much below that of the rest of the country when the entire population of each state is considered but the current income of the farm population per farmer and family shows no such wide disparity. There is an index.



OUR PRIMITIVE CONTEMPORARIES.

By George P. Murdock. The Macmillan Co., New York. \$5.00; Student edition, \$3.60. 7½ x 5½; xxii + 614; 1934.

This seems to us to be about the best general elementary treatise on what the science of ethnology is about, and what its methods and outlook are, that we have yet seen. It digests and condenses an immense amount of original material

published in monographs and books mostly not easily available, and often very dull reading if available, to the end of making plain for some eighteen examples how the "savage" actually lives. It is well written and illustrated. Each of the chapters has at the end a brief but well selected bibliography. There is an excellent detailed index. Altogether we recommend this book without reservation to all students of human biology. Unfortunately many of the half tone illustrations are very badly reproduced.



CLASSIFICATION AND USES OF FINGER PRINTS. (*Seventh Edition*).

By Sir E. R. Henry. *His Majesty's Stationery Office, London; The British Library of Information, New York.* 3 shillings net (Great Britain); 92 cents (New York). 8½ x 5½; iv + 142; 1934.

All you need to know about finger printing is contained in this the seventh edition of Henry's book. There is an interesting although brief resumé of the history of finger printing and an account of some of the uses which have been made of finger prints. Directions for making prints are given, but the most of the book is devoted to description of the identifying characteristics and classification for filing. This latest revision of Henry's original system (which in turn is based on Galton's) makes it the most widely used system of classification.



THE DOCTOR AND CITIZENSHIP.

By Thurman D. Kirchin. *Christopher Publishing House, Boston.* \$1.50. 8 x 5½; 89; 1934.

A collection of short essays about the position of medicine in the community, by the President of Wake Forest College. Nothing new or startling is said, and very much that is trite, and for some time since unoriginal. We gather from the book that the author is a sound, genial, and conservative college president.

ZOOLOGY

IS IT CRUEL? *A Study of the Condition of Captive and Performing Animals.*

By T. H. Gillespie. *Herbert Jenkins, London.* 6 shillings net. 8½ x 5½; 182 + 16 plates; 1934.

This is a book which will interest all animal lovers and bring solace to those who have deplored the captivity of wild animals. The author, director of the Zoological Park in Edinburgh, shows quite conclusively the advantages which a wild animal in captivity has over those that are unconfined, provided of course that the zoo is well kept. In the native state there is constant warfare carried on for the preservation of life. In the zoo, animals very soon adapt themselves to their cages which become to them a safe refuge and frequently develop a real affection for their keepers. A number of instances are cited of animals that, finding means of exit from their enclosures, were accustomed to roam the park at night but always returned before day-break to spend the day in confinement. The rhythmic pacing or movements of the body which so many animals exhibit in captivity Mr. Gillespie believes to be common among many wild animals whether captive or free and enjoyed by them in possibly the same way that the dance is enjoyed by human beings. The second section of the book is devoted to performing animals and the third and final section to the development of zoological parks. The volume contains a number of well-chosen illustrations and is indexed.



ANATOMY OF ANIMAL TYPES for Students of Zoölogy.

By E. A. Briggs. *Angus and Robertson, Sydney.* 10s. 6d. 8½ x 5½; xix + 250; 1934.

This guide for the study of animal types, both invertebrate and vertebrate, will probably have little practical appeal for American zoölogists since it concerns itself only with Australian forms. The book will undoubtedly find friends in Australia, however, for it seems quite complete, authoritative and clearly

written. The author has purposely omitted using any drawings and diagrams holding the view, "... that practical zoölogy is the study, not of drawings and diagrams, but of animal life in all its phases of structure and function." Whether it is desirable to omit illustrations in this case must be determined by the users of the volume. This conservative reviewer however, used to seeing a picture of an *Amoeba* as he studied it, felt keenly the absence of drawings.



COCCIDIA AND COCCIDIOSIS of Domesticated, Game and Laboratory Animals and of Man.

By Elery R. Becker. Collegiate Press, Ames, Iowa. \$2.50. 9½ x 6½; ix + 147; 1934. Besides being based on the author's extensive experimental investigations in the field, this book also embodies a digest of the related literature which runs to some 350 references. The work covers information on species, hosts, host-specificity, life cycle, pathogenicity, immunity, prophylaxis and therapeutics. There are twenty-five plates and text figures which are indispensable for identification and description. Three appendices contain: Recommended readings for coccidiosis in hosts not extensively treated in the text, a host-catalogue of genera of coccidia represented in the vertebrates, and notes on technique. There are both author and subject indices.



TROPICAL FISHES for a Private Aquarium.

By Christopher W. Coates. Liveright Publishing Corp., New York. \$2.00. 7 x 5; xi + 226; 1933.

If you have ever had a gold fish you will like this book, although gold fish are not discussed. The foreword says that not all the fishes suitable for aquaria are listed, but there are over a hundred different species in the index, so that one ought to find a fish to meet almost any specifications. There are 57 excellent photographs. The first four chapters are concerned with general information about aquaria, care and feeding of fish, but the bulk of the book is

devoted to descriptions of species suitable for pets. This is an excellent book since it not only contains valuable information but is delightful reading as well.



THE ELASMOBRANCH FISHES. Third Edition.

By J. Frank Daniel. University of California Press, Berkeley. \$5.00. 10½ x 6½; xi + 332; 1934.

A third edition of this valuable zoölogical text revised by the addition of new material on the transformation of the endostyle into the thyroid gland; a more complete discussion of the lymphatic system; a consideration of the homologies of the carotid artery between Elasmobranchs and higher Vertebrates, and a report of new studies on the nature of the cells forming the wall of an ampulla of Lorenzini.



KURZE ANWEISUNG FÜR ZOOLOGISCH-SYSTEMATISCHE STUDIEN.

By Bernhard Rensch. Akademische Verlagsgesellschaft, Leipzig. 6.20 marks. 9½ x 6½; 116 (paper).

This is a most useful and clear discussion of the principles governing taxonomy and terminology. It is designed to explain briefly modern systematic categories and nomenclature to those who are specialists in other fields of biology, but need nevertheless some understanding of systematic zoology. There is a final section of sound advice to the prospective *Systematiker*. The book is not overlaid with examples and consequently makes easy as well as highly instructive reading.



INSECTS AS MATERIAL FOR STUDY. Two Inaugural Lectures Delivered on 17 and 24 November 1933.

By G. D. Hale Carpenter. Oxford University Press, New York. \$1.00. 9 x 6; 38; 1934 (paper).

Two short essays, delivered as lectures, present the author's opinions as to the desirability of insect material for the study

of biological problems. In general, Professor Carpenter is impressed with the insects as subjects to be used in analyzing problems of ecology and evolution. Of especial interest are the author's views as to the adaptive value of mimicry and protective coloration among insects and the relation of these phenomena to natural selection.



THE TERRARIUM. *Tortoises, Other Reptiles and Amphibians in Captivity.*

By Burgess Barnett. *Poultry World*, London. 1s. 6d. net. $7\frac{1}{2} \times 4\frac{1}{2}$; 57; no date (paper).

A book designed to popularize the "quiet delights of reptiles and amphibians as pets." It includes directions as to feeding and housing and descriptions of such species of reptiles and amphibians as are suitable for vivaria and greenhouses.



BOTANY

THE COMPARATIVE ANATOMY OF EXTRA-CHROMOSOMAL TYPES IN DATURA STRAMONTIUM. *Carnegie Institution of Washington Publication No. 451*

By Edmund W. Sinnott, Helen Houghtaling and Albert F. Blakeslee. *Carnegie Institution, Washington, D. C.* \$1.50 (paper); \$2.50 (cloth). $10 \times 6\frac{1}{2}$; 50 + 19 plates; 1934.

This quantitative analysis of the histological characters of *Datura* mutants of known chromosomal constitution is principally concerned with the structure of the floral pedicel; the leaves of the various types were relatively constant in structure, the stem never really stops developing and comparable sections are hard to find, and the roots were too highly variable within one and the same type for comparison with other types. As might have been expected, the various polyploid types, $1n$, $2n$, $3n$, and $4n$ showed differences in cell and organ size corresponding to their chromosome content. The principal point of interest is the analysis of heteroploid types, diploid plants with a single extra chromosome. Primary mutants

differ very little from the structure of diploid plants but secondary mutants tend to have vascular bundles which are distinctly wider and greater in area than those of diploid. The differences between mutants were mostly of a quantitative character. Besides tables of data there are photomicrographs of representative flower stalks of each of the mutants. As the first histological study of plant hybrids that is not limited to the F_1 generation this contribution deserves the attention of geneticists.



THE FLORA OF ICELAND AND THE FÆROES.

By C. H. Ostenfeld and Johs. Grøntved. *Levin and Munksgaard, Copenhagen*. D. Cr. 6.50. $7\frac{1}{2} \times 5\frac{1}{2}$; xxiv + 195 + 2 maps; 1934.

The senior author finished the first half only of this descriptive manual before his death in 1931 and the work was completed by Johs. Grøntved of Copenhagen with the assistance of specialists on several of the difficult genera like *Hieracium* and *Salix*. It provides analytical keys for the identification of the vascular cryptogams and the seed plants of Iceland and the Færoes, with notes on their distribution and on the colloquial names by which they are known to the inhabitants. There are maps to make the place names intelligible, and there are glossaries and indices which make the book readily usable. It is interesting to note that about half of the genera are represented by only one species. This flora should be very useful to students of plant distribution since many North American plants are represented.



THE MYXOMYCETES. *A Descriptive List of the Known Species with Special Reference to Those Occurring in North America.*

By Thomas H. Macbride and G. W. Martin. *The Macmillan Co., New York*. \$6.00. $9\frac{1}{2} \times 6\frac{1}{2}$; x + 339 + 21 plates; 1934.

This manual is a monographic treatment of the myxomycetes of the world based

on the senior author's *The North American Slime Moulds* and amplified to include all the species thus far described. Analytical keys and full descriptions are provided with critical notes on each species. The taxonomy of these forms presents considerable difficulty and since discriminations between names and authorities necessarily must be made frequently it is a commendable thing to discuss the reasons for the choice as fully as the authors have. Considerable space is given to lists of synonyms and citations of the original descriptions. There is an index and a bibliography. There are 21 plates illustrating habit, spore form, and structure of a large number of species.



DAYLILIES. *The Wild Species and Garden Clones, Both Old and New, of the Genus Hemerocallis.*

By A. B. Stout. The Macmillan Co., New York. \$3.00. $9\frac{1}{2} \times 6\frac{1}{2}$; x + 119 + 36 plates; 1934.

The collections of daylilies at the New York Botanical Garden provided the material on which this manual is based. It describes the species and horticultural clones grown in this country in some detail and there are recommendations as to soils, treatment, and suitability for the garden. There are numerous photographs, four color plates reprinted from Addisonia, a key to species, and an index. Altogether it should be a very satisfactory book for horticulturists and gardeners.



EPITOME OF BOTANY WITH QUESTIONS AND ANSWERS. Part 1.

By G. A. Kapadia. G. A. Kapadia, Rothfield St., Broach, India. 8 annas. $7\frac{1}{2} \times 4\frac{1}{2}$; 44; 1933 (paper).

This syllabus has about the same content and style as a well-bred student's notes on a lecture course on plant morphology. The principal object is to teach the student the names of the structures which have

diagnostic value in classification. There is a short, unillustrated glossary of botanical terms, a list of Greek and Latin root-words, and a list of questions on the material covered in the booklet. Although this could be used to supplement a second-rate textbook profitably there would be no advantage in using it with a good textbook.



A TEXTBOOK OF SYSTEMATIC BOTANY. Second Edition.

By Deane B. Swingle. McGraw-Hill Book Co., New York. \$2.25. $9 \times 5\frac{1}{8}$; xv + 270; 1934.

This is the second edition of a college textbook planned not only to teach students how to identify plants and to provide them with glossaries and diagrams to aid in interpreting the standard manuals, but also to introduce them to the logical principles underlying schemes of classification. Brief synopses are given of 60 families of spermatophytes. There is an index and there are lists of reference books.



MORPHOLOGY

INTERCORTICAL SYSTEMS OF THE HUMAN CEREBRUM. Mapped by Means of New Anatomic Methods.

By Joshua Rosett. Columbia University Press, New York. \$3.00. 10×7 ; xvi + 135; 1933.

In this book the author describes his work in mapping out the intercortical nerve fibres by the ingenious method, devised by him, of dissecting the tissues along the natural lines of cleavage by exploding them with gas. Although much more work will have to be done before definite results can be obtained concerning special regions and functional mechanisms, the work is important as orientation for further study. Adolf Meyer contributes a foreword and Stanley Cobb a preface. The bibliography contains 65 titles and there is an index.

L'UTILISATION DE LA CHARPENTE OSSEUSE PAR LES ANIMAUX VERTÉBRÉS. *Deuxième édition revue et augmentée.*

By Louis Perbal. G. Doin et Cie, Paris. 25 francs. 9½ x 6½; 162; 1934 (paper).

The author has added about 60 pages to his earlier edition noticed in Volume 7, p. 476 of the REVIEW, but leaves us still unconvinced that his examples of adaptation of skeletal structures of animals prove conclusively that the Lamarckian theories of evolution are so.



PHYSIOLOGY AND PATHOLOGY

FEATURES IN THE ARCHITECTURE OF PHYSIOLOGICAL FUNCTION.

By Joseph Barcroft. *The University Press, Cambridge; The Macmillan Co., New York.* \$5.50. 8½ x 5½; x + 368; 1934.

The argument that runs through this series of lectures is that the fundamental principles of human physiology are interdependent, that in a certain sense one principle implies the others.

At the outset I had regarded the body as a noble building on the principles which it exhibits as unconnected features in its architecture. It became clear that the features were far from being independent. The highest functions of the nervous system demand a quite special constancy in the composition of its intimate environment. The stability of the internal *milieu* almost compels the principle of the storage of materials and of integration in adaptation. Again an easy stepping stone to integration in [is] the practice of the body to have more than one way of doing many things. But parallel mechanisms may express themselves not only in integrative but in antagonistic processes. Moreover, increased function actively may be achieved either by heightening the efforts of units already functioning or marshalling a greater number of units; and so we arrive at the "all-or-none" relation.

It seemed almost as though there had emerged an approach to physiology from an unusual angle: not from that of mere structure, whether the structure of organs or of chemical formulae, but from the principles of function.

This, then, is the outline of a thorough-going and critical review of quantitative evidence on which this series of propositions rests presented skillfully in the form of lectures. It is an impressive chain of reasoning but it would be unfair to say

that it makes easy reading; it requires careful study but it is worth it. Bibliographies and an index are provided.



STUDIES ON THE POSSIBLE INTOXICATING ACTION OF 3.2 PER CENT BEER.

By A. J. Carlson, N. Kleitman, C. W. Muehlberger, F. C. McLean, H. Gullicksen and R. B. Carlson. *University of Chicago Press, Chicago.* 75 cents. 9 x 5½; vii + 85; 1934 (paper).

A laboratory experiment designed to be helpful in a redefinition of alcoholic intoxication in its social and legal aspects. The specific question to be answered was: Can sufficient beer containing 3.2 per cent alcohol be consumed to produce definite intoxication? The beer was given to human subjects under experimental conditions. The measurements taken were: Alcoholic concentration in blood and urine, a series of objective performance tests, and subjective judgments of change in behavior of the subjects by observers. The amounts of beer given were graded from two 12-ounce bottles up to quantities taxing the capacity of the digestive tract with repetition of dosage at various time intervals and with and without food. A check test was carried out using near beer. The data are presented in tables, charts and correlation surfaces. A brief review of experiments dealing with intoxication is made, but an extensive comparison of the findings is impossible for lack of statistical data in previous studies. The authors found that forced consumption of 3.2 per cent beer at the rate of 4 to 6 bottles per hour for three and one-half hours (109 cc.-190 cc. of alcohol) produced intoxication in five out of 29 cases. The average blood concentration of alcohol was 1.2 milligrams per cc., which was within the range where 40-46 per cent were found "under the influence" or at the stage of "stimulation" by other investigators, and this concentration is below the limit of intoxication set by the British Alcohol Investigation Committee. The authors conclude that 3.2 per cent beer is not intoxicating, for the ordinary person cannot practically drink large enough quantities

necessary to reach the required alcohol concentration in the blood.



DISEASES PECULIAR TO CIVILIZED MAN.
Clinical Management and Surgical Treatment.

By George Crile. Edited by Amy Rowland.

The Macmillan Co., New York. \$5.00.

8½ x 5½; xi + 427 + folding chart; 1934.

The principle enunciated here is that the high activity of the brain, the thyroid, and the adrenal-sympathetic system of civilized man gives him not only his unique power and distinction, but also his unique diseases, neurocirculatory asthenia, hyperthyroidism, peptic ulcer and probably diabetes. Treatment of these hyperkinetic syndromes includes one or more points of attack, the object in each case being to lessen the factors that are causing the damaging kinetic drive; thus the driving power of the brain may be lessened by rationalization or by excision of the sympathetic ganglia, the driving power of the thyroid decreased by thyroidectomy or by interference with its sympathetic nerve supply by ligation, the hyperactivity of the adrenals by denervation. Of these possible points of attack, primary emphasis is placed on adrenal denervation. Under this treatment, 94 per cent of 76 cases of true neurocirculatory asthenia, the same percentage of 79 cases of hyperthyroidism, and 96 per cent of 37 cases of peptic ulcer, showed cure or improvement.

Approximately the first one-third of the book deals with the development of the theory of the interrelated hyperkinetic activity of the brain-thyroid-adrenal-sympathetic system, clinical descriptions of the "diseases peculiar to civilized man" and the surgical technique of adrenal denervation. The remainder of the book is devoted to routine clinical histories of patients, most of whom were treated by adrenal denervation. Although joint authorship is not noted on the title page, parts of the book are contributed either by or with the assistance of five coworkers. In its entirety, however, the book reveals the boundless enthusiasm and unbridled optimism of the principal author. An extensive bibliography and name and subject indexes are included.

LES ULTRAVIRUS. *Pathogènes et Saprophytes. Techniques d'Étude. Caractères Physiques et Biologiques. Maladies à Ultravirus. Clinique. Anatomo-Pathologie. Épidémiologie. Immunité.*

By Paul Hauduroy. Masson et Cie, Paris.

60 francs. 10 x 6½; 462; 1934 (paper).

Although this might be called a second edition of the author's book *Les Ultravirus et les Formes Filtrantes des Microbes* published in 1929 and noticed in these columns (Vol. 5, pp. 364-365) it is really a different work. Interest and research on the viruses has advanced to such an extent as to add to, modify or negate much of the material presented in the previous work. The arrangement of the section dealing with specific viruses—those affecting bacteria, plants, fishes, insects, and birds as well as mammals—follows in the main that of the earlier work, but it has been entirely rewritten to conform with the knowledge which subsequent research has brought to light. The author has added a section on techniques as bases for further study, but has omitted the discussion of filtrable forms of non-filtrable germs, as he intends to devote another book to this phase. The book is well-written, well documented and indexed, and should altogether make a worthy addition to the bacteriologist's library.



L'IMMUNITÉ PAR MÉCANISME PHYSICO-CHIMIQUE.

By R. Dujarric de la Rivière. Masson et

Cie, Paris. 18 francs. 9½ x 6½; 73; 1934 (paper).

For ten years the author has conducted numerous investigations to determine the physicochemical mechanism underlying immunity. In this volume he briefly summarizes the results of a few of his experiments as an illustration of the value of biochemical and biophysical methods and technique. The monograph is divided into three parts. In the first he reports the changes occurring in the antiseptic power of certain compounds through the action of ultraviolet radiation and in relation to difference in electrolytic disassociation. The second treats of the preciseness of the flocculation technique from which

Ramon's work on diphtheria anti-toxin derives its importance. In the last and most extensive part the author demonstrates the function of the hemoglobin, adsorption and transportation of toxins and antitoxins, and in particular the effect of bismuth, arsenic and mercury compounds on the red blood cells of man (syphilitic and non-syphilitic) and other animals.



DIET AND PERSONALITY. *Fitting Food to Type and Environment.*

By L. Jean Bogert. The Macmillan Co., New York. \$2.00. 7½ x 5½; ix + 223; 1934.

Advice as to what to eat and when to eat it is not lacking in the lives of most of us. Sensible advice, that which is free from superstitious prejudice or is not advanced for the commercial advantage of somebody and which takes any account whatsoever of individual differences is not however, accessible to a vast number of persons. In this book Doctor Bogert presents, in clear although somewhat breezy style, most of what the relatively new science of nutrition has to teach the practical man about his diet. In addition, as she says in the Foreword, "You may find that I have almost as much to say about general living conditions and health habits as about diet, but that is because no one can profit from a good diet as much as he should, when his habits of living are wrong . . ."



TRAITÉ DE PHYSIOLOGIE NORMALE ET PATHOLOGIQUE. Tome VII. Sang et Lymph. Réactions d'Immunité. (Deuxième Édition).

By Ch. Achard, Justin-Besançon, A. Besredka, Léon Binsz, J. Bordes, L. Cuthner, H. Delaunay, R. Fabre, J. Jolly, M. Laudat, Ph. Pagniez, G.-H. Roger, E. Schulmann, P.-E. Weil, E. Zung. Published under the direction of G.-H. Roger and Léon Binsz. Masson et Cie, Paris. 100 francs (paper); 120 francs (cloth). 9½ x 6½; xii + 731; 1934.

Since 1927 when the first edition of this volume (noticed in these columns, Vol. 3,

p. 143) of a useful reference work on physiology appeared research has increased the knowledge concerning blood and lymph to such an extent that the material had to be thoroughly revised and augmented to make the second edition up-to-date. Notable additions include a chapter on the chemical constituents of blood written by M. Laudat, and one by L. Cuénot on the coagulation of the blood in the invertebrates. A chapter by Edgard Zung on coagulation has been substituted for Doyon's treatment of the subject which appeared in the first edition. The documentation has likewise been brought up through 1933 and the whole book is more than 200 pages longer than the earlier work.



HOMMAGE À LA MÉMOIRE DU PROFESSEUR JEAN CANTACUZÈNE. Tome I et II.

Masson et Cie, Paris. 250 francs. 11 x 7½; xv + 822; 1934 (paper).

Doctor Ion Cantacuzino was born in Rumania, completed his medical and bacteriological education in Paris, was connected for several years with the Pasteur Institute, and for the last thirty-two years of his life occupied the Chair of Experimental Medicine in the Faculty of Medicine and the Institute of Pathology and Bacteriology in Bucharest. He died in January of this year. It was originally planned to present these two volumes of papers by his students and friends to him on the occasion of his seventieth birthday in November.

The papers treat of bacteriological and pathological subjects. The list of contributors is a long and imposing one, but space permits us to mention only a few: A. Besredka, A. Boquet, A. Calmette, S. Metalnikov, L. Nègre, P. Reiss, G. Teissier and A. Wadsworth.

A short biography of Doctor Cantacuzino and a list of his publications, 123 in number, are provided.



LOCALIZATION OF FUNCTION IN THE CEREBRAL CORTEX. An Investigation of the Most Recent Advances. Proceedings of the Associa-

tion, New York, December 28th and 29th, 1932.

By Association for Research in Nervous and Mental Disease. Editorial Board: Samuel T. Orton, John F. Fulton and Thomas K. Davis. The Williams & Wilkins Co., Baltimore. \$8.00. 9 x 5½; xxi + 667; 1934.

A series of papers by thirty-four well known contributors, on aspects of cerebral localization, presented at the thirteenth annual meeting of the Association for Research in Nervous and Mental Diseases on December 28-29, 1932. The volume is divided into three sections representing three different attacks on the problem. The first, the anatomical, indicates the structural differences of various parts of the cortex; the second section deals with the experimental aspect which points towards the variation in functional importance of the same cortical area in animals of different phylogenetic levels. The third attack is from the standpoint of detailed clinical observation, particularly on people who have undergone lobectomies.



THE HUMAN BODY. *Its Structure and Activities and the Conditions of Its Healthy Working.*

By H. Newell Martin. Twelfth Edition, Thoroughly Revised by Ernest G. Martin. Henry Holt and Co., New York. \$4.00. 8½ x 5½; xv + 701; 1934.

The twelfth edition of this excellent textbook follows the pattern of the preceding one but is augmented and modified in accordance with recent discoveries. It is as complete and clear an outline of human anatomy and physiology as could possibly be written for the college student.



BIOCHEMISTRY

THE PHYSICO-CHEMICAL PROPERTIES OF PLANT SAPS IN RELATION TO PHYTOGEOGRAPHY. *Data on Native Vegetation in its Natural Environment.*

By J. Arthur Harris. Compiled from Original Records and Edited by a Committee of Dr. Harris' Colleagues in the University of Minnesota. University of Minnesota Press, Minneapolis. \$4.50. 9½ x 6; vi + 339; 1934.

A unique situation is involved in the publication of this volume. The laboratory records and field notes of the late J. Arthur Harris collected over a period of about eighteen years and hitherto unpublished have been collected and tabulated by men formerly associated with him, and are now offered to physiologically-minded ecologists for interpretation. Professor Harris undertook a very extensive survey of the physico-chemical properties of the tissue fluids of representative plants from very diverse ecological habitats intending to "analyze the data from two standpoints: first, the extent to which the plant's adaptability to environment—as measured by its ability to vary the physico-chemical properties of its tissue fluids—is a factor in plant geography and the evolutionary process; and, second, the physical and chemical properties of the environment as a determining factor in the distribution of plant forms." His data include depression of the freezing point of the expressed sap and the osmotic pressure calculated therefrom; the specific electrical conductivity, expressed in ohms; pH value, chloride content and sulphate content; and for each plant the full scientific name and notes on its habitat. About 12,000 such records are presented here in systematic fashion and the problem of indexing and cross-indexing and coding has been very nicely solved. There is no attempt at analysis or interpretation. There are, however, notes by Harris setting forth his objectives and explaining his methods, and there is a bibliography of the 44 papers he and his collaborators published on this subject.

It seems to us that this undertaking is an interesting experiment in scholarship; at the death of a competent investigator a large amount of data, too important to be lost, falls into the hands of his literary executors. How can it best be used? This is one way of solving the problem; we are curious to see how it works out.

A BIOCHEMICAL STUDY OF THE METABOLISM OF MENTAL WORK. *Archives of Psychology* No. 164.

By Hyman Goldstein. *Archives of Psychology, Columbia University, New York.*

\$1.00. 9½ x 6½; 57; 1934 (paper).

An important contribution to studies in physiological psychology. The work is divided into two sections: (1) Investigations of tasks involving mental work with overt physical components (cancellation, intelligence test and tapping). The conclusions drawn were that

Increase of the physical component results in greater metabolic change as determined by the biochemical methods employed in this investigation,

Increase of the mental component without increase of physical component does not result in greater metabolic change, as determined by the biochemical methods used in this study.

(2) Investigation of tasks involving mental work with minimum physical component. These studies showed that

Metabolic change, as determined by the biochemical methods of this investigation, does not differ significantly from that which occurs during "no work."

In a discussion of the results obtained the author expresses the belief that

If there are any effects produced by mental work *per se* upon the total metabolic activity, it is evident that the current biochemical methods, particularly those employed in this study, do not appear to be sufficiently sensitive to detect these effects.

There may still be very intense biochemical activity present in particular areas of the brain as a result of mental work without affecting the total body metabolism. The author presents the results of his experiments in tabular form and concludes with a literature list of 67 titles.



HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 428. Quantitative Stoffwechseluntersuchungen.* Containing following articles: *Technik der Messung des Gesamtstoffwechsels und des Energiebedarfes von Haustieren*, by Francis G. Benedict, V. Coropatchinsky and Ernest G. Ritzman; *Zwei elektrisch kompensierte Emissions-Kalorimeter für kleine Tiere und Säuglinge und für Erwachsene*, by Francis G. Benedict.

Urban und Schwarzenberg, Berlin. 6.50

marks. 10 x 7; pp. 619-750; 1934 (paper).

The first of the papers describes the buildings, stalls, and apparatus developed at the Agricultural Experiment Station at Durham, New Hampshire, for respiration and nutrition studies on cattle and horses. No one who has ever lived on a farm can fail to be impressed by the automatic mechanical device, described and illustrated in detail, for the collection, removal, and storage of manure.

The second paper describes two types of a differential calorimeter much better adapted for short time metabolism experiments on man and small animals than the older and more massive chambers which sometimes weighed fifteen times as much as the person being studied.

Both papers are thorough and are well illustrated.



THE CHEMISTRY OF THE HORMONES.

By Benjamin Harrow and Carl P. Sherwin. *Williams & Wilkins Co., Baltimore.*

\$2.50. 9 x 6; vii + 227; 1934.

A practical book for the laboratory worker who wishes to prepare active hormone fractions of a chemically pure hormone. The main emphasis is on the chemical procedure. However, of necessity, considerable biological information is woven into the very clearly written exposition. Historical information with reference to discoveries and development of techniques forms a secondary but interesting phase of the discourse. There is a chapter devoted to each of the following: Thyroid; parathyroid; pituitary; adrenal; male, female and plant hormones; insulin; and secretion. Each chapter has its extensive list of references, and the volume is indexed by author and by subject.



MEDIZINISCHE KOLLOIDLEHRE. *Lieferungen 10 und 11.*

Edited by L. Lichtwitz, *Raph. Ed. LieSEGang and Karl Spiro. Theodor Steinkopff, Dresden.* 5 marks each. 10½ x 7½; Lief. 10, pp. 689-768; Lief. 11, pp. 769-848; 1934 (paper).

Previous numbers of this series on the

application of colloid research to medicine have been noticed at various times in these columns. The present *Lieferungen* contain the following papers: Liver and gall; spleen, both by K. Hinsberg and T. Wedekind; The lung and upper respiratory tract and the nervous system, by R. E. Liesegang; The smallest organisms and disinfection, by H. Reiche; Dietetics of childhood with special consideration of milk, by K. Scheer; Dietetics of adults, by W. Heupke, and H. Lampert; and Balneology, by R. E. Liesegang.



ANNUAL REVIEW OF BIOCHEMISTRY. *Volume III.*

Edited by James M. Luck. Stanford University Press, Stanford University, Calif.
\$5.00. 8½ x 6; viii + 558; 1934.

The third annual volume of this exceedingly useful review of selected topics in biochemistry is as well done as its predecessors. There is a good deal of flexibility in the choice of the subject matter treated; some topics are reviewed only biennially, and some less active fields are to be treated more infrequently still. Two subjects appear for the first time in this volume, reviews of the biochemistry of malignant tissues and of dentistry.



INTRODUCTION TO PHYSIOLOGICAL CHEMISTRY. *Third Edition.*

By Meyer Bodansky. John Wiley and Sons, New York. \$4.00 net. 9 x 5½; xi + 662; 1934.

Many sections of the third edition of this excellent textbook have been revised to include new data which have appeared since the last edition. The discussions of the chemistry of enzymes, the regulation of gastric activity, muscle metabolism, the mineral requirements in nutrition, the vitamins, hormones, blood and other body fluids, have been enlarged.

ÉLÉMENTS DE CHIMIE ORGANIQUE BIOLOGIQUE. *Introduction Chimique à l'Étude de la Biologie Générale.*

By Michel Polonovski and Albert Laspagnol. Masson et Cie, Paris. 100 francs. 10 x 6½; 594; 1934 (paper).

This is an excellent, systematically arranged introduction to biochemistry. All the groups of compounds basic to plant and animal life are discussed, and technical instructions given. Although primarily intended for the use of physiologists, the biologist, physician, pharmacologist and chemist should find it a handy reference book. The index is very complete.



SEX

THE REVOLUTIONARY IDEAS OF THE MARQUIS DE SADE.

By Geoffrey Gorer. Wishart and Co., London. 8s. 6d. net. 8½ x 5½; 264; 1934.

The portrait which Mr. Gorer draws of the Marquis de Sade is very different from the fabulous monster of tradition. De Sade was a radical in politics and an experimentalist in sex. In the former capacity he made influential enemies who used his sexual experiments as a pretext to ruin him.

... if de Sade on several occasions indulged in abnormal pleasures, he also risked his life to save that of a woman who had caused him to be imprisoned for thirteen years; ... if a psychologist has attached his name to a form of cruelty, he was actually an inveterate opponent of capital punishment.

In his political writings de Sade escaped the uncritical optimism which led many of his contemporaries to look forward to an immediate establishment of Utopia.

He had no illusions about the natural goodness of man, but he believed that with complete economic and sexual equality human conditions could be greatly bettered. He anticipated the views of Malthus on population, and the tolerance of the Danish penal code as regards sexual behaviour.

As a writer on the psychology of sex de Sade was a pioneer in a significant field of human biology. Unfortunately, however important the study of the sexual perversions may be, its spectacular character has had the effect of drawing away the atten-

tion of investigators of sexual psychology from the still more important study of normal sexual behavior. Mr. Gorer considers that Krafft-Ebing's definition of sadism as "sexual emotion associated with the wish to inflict pain and use violence" reflects a misunderstanding of de Sade's own viewpoint and that it would be preferable to use Schrenck-Notzing's term *alogagnia* for all activities in which sex and external pain are united and to "keep the word Sadism for the special group of instincts which de Sade was the first and almost the only person to describe and which constitutes by far his most important contribution to psychology." Mr. Gorer's proposed redefinition of sadism is "the pleasure felt from the observed modifications on the external world produced by the observer. . . . Like all human emotions this is ambivalent, and can be either constructive or destructive." In other words Mr. Gorer would equate sadism with the pleasure of self-expression.

. . . there can be Sadistic satisfaction in painting a picture, but not in painting a house under another person's orders and following another person's taste; there can be Sadistic pleasure in killing a person, but not if that killing is ordered and independent of the killer.

The book includes a foreword by J. B. S. Haldane and a bibliography covering four pages of books by and about de Sade, but unfortunately it lacks an index.



GENEALOGY OF SEX. *Sex in its Myriad Forms, from the One-Celled Animal to the Human Being.*

By Curt Thesing. Translated from the German by Eden and Cedar Paul. Emerson Books, New York. \$5.00. 8½ x 5½; xii + 286; 1934.

This book on sex is interesting. Some biologists may consider it sensational and anthropomorphic, and some specialists (as specialists alone can do) will undoubtedly find factual errors within; nevertheless, the writings capture the interest of the reader and hold it. The author has collected a commendable number of natural history observations dealing with various behavior reactions associated with sexual

processes throughout much of the animal world. He has arranged the material in the form of a 'genealogy' in that he attempts to depict the development of the sex impulse and its consummation from primitive to complex forms. He discusses the sex secrets of spiders, squid, crayfish and toads with the same realistic enthusiasm as he shows in dealing with the human organism. The book merits reading. [Reginald the Office Boy liked the last chapter best.]



RECENT ADVANCES IN SEX AND REPRODUCTIVE PHYSIOLOGY.

By J. M. Robson. P. Blakiston's Son and Co., Philadelphia. \$4.00 net. 7½ x 5½; x + 249; 1934.

This book really is what the title says it is—recent work on sex physiology. A knowledge of the anatomy and physiology of sex organs is assumed and the chief topic considered is the recent work on the sex hormones. There is no single list of references, but separate lists are given at the end of each chapter. The citations are much abbreviated, titles of the papers not being included. There is, however, an author index and a good subject index.



BIOMETRY

CONTINUOUS INVESTIGATION INTO THE MORTALITY OF ASSURED LIVES. *Statistics for the Six Years 1924-1929.*

Published on behalf of The Institute of Actuaries and The Faculty of Actuaries in Scotland. University Press, Cambridge; The Macmillan Co., New York. \$15.00. 9½ x 6; xxxiv + 675; 1933.

This book tabulates the combined experience of a large number of British and a few Canadian and Australian life insurance companies for the years 1924-1926 and 1927-1929. Policy holders subject to extra risk are excluded. Medically examined lives and those not 'medically examined' are treated independently, while under each section the four classes of insurance—whole life with profits, whole life without profits, endowment with profits,

and endowment without profits—are tabulated separately. In each table the deaths and policies in force as well as the exposed to risk and unsmoothed rate of mortality based on them are given. The total experience represents over ten million person-years of exposure to risk and 121,094 deaths.



BIOMETRIA E ANTROPOMETRIA. *Trattato Elementare di Statistica Vol. III.*

By Marcello Boldrini. Antonino Giuffrè, Milano. L. 50. $9\frac{1}{2} \times 6\frac{1}{2}$; xiii + 464; 1934. This is one of a series of volumes on elementary statistics published under the auspices of the Istituto Centrale di Statistica of Italy. It summarizes rather thoroughly, although often with ineffectual criticism, statistical applications in the field of biology: problems of growth, evolution, genetics, anthropology, somatic constitution. The exposition is very clear and the bibliography complete. There is an index of eighteen pages.



PSYCHOLOGY AND BEHAVIOR

MODES OF BEHAVIORAL ADAPTATION IN CHIMPANZEE TO MULTIPLE-CHOICE PROBLEMS. *Comparative Psychology Monographs, Vol. 10, No. 1, Serial No. 47.*

By Robert M. Yerkes. The Johns Hopkins Press, Baltimore. \$1.50. $10 \times 6\frac{1}{8}$; 108; 1934 (paper).

Unfortunately the results of this interesting series of experiments can only briefly be given. Four sexually immature chimpanzees (3 female, 1 male) served as subjects in the experiments which were undertaken to determine "(a) whether, and if so under what conditions, solution of a certain type of novel problem occurs suddenly, as if by discovery and with insight; (b) optimal motivational conditions for problem solution; (c) whether adaptation to relational problems may be achieved in radically different ways, as by trial and error versus discovery." Of 24 problems 14 (58%) resulted in solution. In 6 of the 14 cases the error was abruptly eliminated after 3 or more mistakes. The

remaining 8 successful adaptations were mostly achieved by "gradual approximation to perfection of response." The experiments are given in detail together with their summary in tabular and graphic form. The author believes that the following practically and theoretically significant generalizations are justified:

(a) Motivational factors are of two sorts, barring intermediates and mixtures; (1) those which primarily influence general activity, interest, and alertness, and (2) those which affect specific responses. In this investigation the former appeared to be indispensable, whereas the latter were of slight or even negative value.

(b) Given excellent general adaptation to the experimental situation and the experimenter, together with willingness to cooperate by making the circuit through the multiple-choice apparatus a certain number of times daily, marked stimulation by the use of motivational factors interfered with the solution of relational problems by chimpanzee.

(c) It is indicated that special rewards and deterrents neither reinforced correct responses nor inhibited incorrect responses, for the fairly obvious reason that the same response might be correct for one setting of the apparatus and incorrect for the next."

The study concludes with a brief list of references.



A FIELD STUDY OF THE BEHAVIOR AND SOCIAL RELATIONS OF HOWLING MONKEYS. *Comparative Psychology Monographs, Vol. 10, No. 2, Serial No. 48.*

By C. R. Carpenter. The Johns Hopkins Press, Baltimore. \$2.25. $10 \times 6\frac{1}{8}$; 168; 1934 (paper).

The author spent about eight months studying howling monkeys in the Panama Canal Zone and in the Republic of Panama. Most of the intensive study was made on the Island of Barro Colorado, where it was possible to keep groups under observation day after day.

The howling monkeys live in clans varying in size from four to 35 individuals. A clan tends to occupy a definite and limited territory through which it moves in reference to lodge and food trees at about the rate of eight hundred yards per day. The males usually lead the group and when they encounter potential danger, or other groups of howlers, noisy vocal battles result and the group soon shifts its course

to avoid contact. The author sometimes met with howls and bluff, often accompanied with showers of sticks and dung, before flight or indifference was shown.

Among adults in a group the sex ratio is approximately 28 per cent males to 72 per cent females. Mating is apparently communal with some preference among individuals. The males are peaceful and coöperative toward all members of the clan. At times single males become separated from a clan and frequently when these complementary males attempt to join a strange group they are driven away temporarily by vigorous vocalization.

The young are infants in arms for about one month, then they ride their mother's hip until nearly a year old. During the second year the young follow the mother more or less closely. The young are weaned and the tendency for play is at its height. Toward the end of the third year play habits decline, sexual development takes place and the young become sober old monkeys.

There are sixteen pages of illustrative plates, a bibliography of 74 titles, and an index to this very interesting study of monkey society.



THE PHILOSOPHY AND PSYCHOLOGY OF SENSATION.

By Charles Hartshorne. University of Chicago Press, Chicago. \$3.00. 9 x 6; xiv + 288; 1934.

Here we have presented to us the theory of the Affective Continuum which, according to the author, is the foundation of intersensory resemblances. It

implies that whatever qualities exist can be related as variables intersecting in the same system. It also implies that qualities of human experience correspond in some degrees to the qualities of neural and somatic cellular experiences which by the bond of sympathy which is the psycho-physical relation, form their physiological conditions." A characteristic example will render the meaning clearer: "the smell of a skunk—which in moderate intensity may be enjoyed—is a bitter like smell, a bitterness differently spatialized from that of the taste of strychnine, but plainly akin to it."

The greater part of this work deals especially with visual and auditory sensa-

tions. Aside from minor inaccuracies such as that the wave-length of the visible spectrum is from 400 to 800 millimeters, we are introduced to a derivation of the affective continuum, e.g., "the brightness of highly pitched sounds." The author affirms that if this fact and its implications had been seriously considered by physiologists, the Wever-Bray phenomenon would have been discovered long ago. Not being a philosopher we cannot understand how nor where the author derives the erroneous assertions that nobody is deaf to the brightness range (the upper limit of which is apparently regarded by the author as 800 cycles).

From the viewpoint of an empiricist, the examples given above, together with the statement that some of the evidence discussed is based only on intuition, the disregard of experimental data and last but not least the appendix on the applicability of the affective continuum to theology, are sufficient to classify this book as an attempt to reduce psychology to its primitive sterile status. In our opinion the author achieves clearness of language and expression only in discussing matter of his own specialty and we find worthy of particular praise his pages on aesthetics.



WHO SHALL SURVIVE? *A New Approach to the Problem of Human Interrelations.*

By J. L. Moreno. Nervous and Mental Disease Publishing Co., Washington. \$4.00. 9½ x 6; xvi + 440; 1934.

The student of human relations will find this an interesting book. The author first experienced the need for some definite method of social and psychological planning when a member of a staff which was supervising a group of 10,000 Austrians of Italian extraction who were moved during the World War from their homes in the southern Tyrol to a place near Vienna. The throwing together of such a large group, unselected, unaccustomed to the environment, and unadjusted within themselves produced great unhappiness and friction. To bring about a better social adjustment within this group Dr. Moreno began his first experiments in sociometric planning, later carrying on and extending

and refining his methods among groups in this country, chiefly in public and training schools in and near New York City. He has also been concerned with the psychological planning of communities for the Department of the Interior. Briefly, sociometry is a science which is concerned with the psychological properties of populations and with the communal problems which these properties produce. Sociometry is the mathematical study of these psychological properties. The amount of organization shown by social groups is measured by the sociometric test. By means of this test an individual can make his choice, without restraint, for membership in the group for which he is best fitted. In one of the last sections in the volume the writer discusses the importance of maintaining the *spontaneability* of the individual which requires the concentration of all agencies—technological, psychological and eugenic. The experimental work is illustrated by numerous charts and graphs. Further notes, a glossary, and a bibliography are included in a series of supplements. The volume is indexed.



THE BEHAVIOUR OF ANIMALS. *An Introduction to its Study.*

By E. S. Russell. Longmans, Green and Co., New York. \$4.20. 8½ x 5¾; viii + 184; 1934.

A book which cannot fail to interest its readers. It should be in all biological as well as general libraries. For the general reader interested in natural history no better introduction to the study of animal behavior has appeared. Likewise all students intending to specialize in this line of work will find it valuable reading. Stress is placed on the importance of regarding the animal as an entity rather than studying it as a mere bundle of mechanisms responding to stimuli, on observing and recording fully and accurately an animal's behavior in its daily activities, not only what is unusual but even the simplest responses. The author believes that much valuable knowledge of animal behavior is possessed by game keepers, shepherds, dog breeders, etc. which the professional student has generally ignored.

He does not find Roule's theory that the salmon, when ready to spawn seeks increased quantities of dissolved oxygen in fresh water streams, sufficient to explain why this species seeks a particular estuary or a particular stream which at its mouth frequently contains heavily polluted water which it must pass through before reaching the fresher water. The volume is adequately illustrated, each chapter is well documented and there is an index.



YOU MUST RELAX. *A Practical Method of Reducing the Strain of Modern Living.*

By Edmund Jacobson. Whittlesey House, McGraw-Hill Book Co., New York. \$1.50.

7½ x 5; xv + 201; 1934.

A "handy" book (third printing), based on the author's earlier work *Progressive Relaxation*, whereby Americans can keep up their fast pace of living without too great a strain on the system. Dr. Jacobson, of the University of Chicago, has for many years devoted his attention to neuromuscular tensions and the disabilities which they produce. He has developed a method of relaxation which he strongly recommends to all those who, while physically fit, suffer from exhaustion, insomnia, or nervousness of one kind or another. He gives detailed instructions on how to relax properly even while being active. Progressive relaxation under his system frequently brings improvement where there is no organic disease in cases of indigestion and colitis and he believes that some advancement is being made by the same method in the little understood field of hypertension. Written expressly for the layman the volume is devoid of technicalities. It contains a number of illustrations but is without index.



MECHANISMS OF HANDEDNESS IN THE RAT. *Comparative Psychology Monographs, Vol. 9, No. 6, Serial No. 46.*

By Geo. M. Peterson. The Johns Hopkins Press, Baltimore. \$1.25. 10 x 6½; 67; 1934 (paper).

Right and left handedness seem to occur in

about equal numbers with rats, the ambidexterity occurring less frequently than either of the other conditions. Handedness seems to be a stable characteristic though relatively complex. Chance use or previous experience cannot entirely account for the trait for ambidextrous animals do not acquire a fixed preference for one hand after a greater amount of forced practice with that hand. Seven generations of inbreeding were insufficient to establish a simple Mendelian mechanism for the inheritance of the trait. Cerebral localization of handedness lies in the frontal area of the contralateral hemisphere. Destruction amounting to less than 4 per cent of the area of one hemisphere will lead to transfer in the preferential use of the hands.

Twenty pages of appendices give the tabulated test data, and two pages of plates give 28 diagrams of local cerebral destruction relative to certain rats under test. There is a bibliography of 23 titles.



INTRODUCTION TO PHYSIOLOGICAL PSYCHOLOGY.

By Graydon LaV. Freeman. Ronald Press Co., New York. \$4.50. 8 x 5½; xvii + 579; 1934.

One is tempted to characterize this book as psychology in terms of axial gradients. But that is hardly fair as it would seem to imply that the author is riding a hobby which is not the case. There is more of what is generally taught as biology than is usual in a psychology text. This is to be expected from the author's definition: "the field of physiological psychology covers these investigations and interests which lie between psychology, physiology, and neurology, and which are not paramount to any one of them. It is, in a sense, a hybrid, like physiological chemistry, and serves to emphasize the essential continuity of the sciences."

The book is divided into four main divisions: Basic neural mechanisms in behavior, Structuro-functional organization of neural mechanisms, and Integrative action of neural mechanisms, and neural mechanisms and variable behavior. There are selected references at the ends of the

chapters as well as the regular literature citations given in foot-notes. The index includes both authors and subjects.



KEEPING A SOUND MIND.

By John J. B. Morgan. The Macmillan Co., New York. \$2.00. 7½ x 5½; ix + 440; 1934.

This book puts the findings of psychologists and psychiatrists on mental hygiene into non-technical language for the benefit primarily of college students. Its viewpoint is that mental health depends in large part on the formation of certain mental habits and the elimination of certain others. The chief factor which leads in extreme cases to the functional mental diseases and in less extreme cases to unhappiness and inefficiency is the refusal in one form or other to face reality. Particularly dangerous is the habit of blaming others for our failures. The ascetic ideology which assumes that to be meritorious an activity must be distasteful is also the cause of much maladjustment. "Modern researches have demonstrated that work is man's best friend. It is a means of prophylaxis against mental disease and a therapeutic agent for effecting cures." The book contains a two-page list of references for further reading and an index.



INTRODUCTION TO COMPARATIVE PSYCHOLOGY.

By Carl J. Warden, Thomas N. Jenkins and Lucien H. Warner. Ronald Press Co., New York. \$4.50. 8 x 5½; x + 581; 1934.

This is an excellent reference or text-book, bringing together widely scattered material on the behavior of infra-human organisms. The present volume is an abridged and simplified edition of a larger and more detailed work by the same authors to be called *Comparative Psychology*.

The first six chapters are somewhat general, giving historical background, general aspects of behavior and methods of testing capacities. The last 14 chapters are devoted to the description of the reactions of the different phyla. The same topical

arrangement is maintained from group to group; so one can follow, protective behavior, for example, from amoeba to monkeys. Although that particular subject fares pretty poorly, the book is a storehouse of information.

There are subject and author indices.



CIVILIZED LIFE. *The Principles and Applications of Social Psychology. A Revision and Enlargement of Social Psychology, 1925.*

By Knight Dunlap. The Williams & Wilkins Co., Baltimore. \$4.00. 8½ x 5½; ix + 374; 1934.

This is a revised and enlarged edition of the author's *Social Psychology*, which was noticed in Volume 1, page 137 of this REVIEW. Chapters have been added on desire, race and civilization, and the child as a member of the group. Professor Dunlap intends to elaborate the topics of the family, religion, and politics in separate treatises which will deal with them in more detail than is possible in the present book. An index and an annotated bibliography, in which he tells—sometimes quite pungently—what he thinks of the books cited, are included.



DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

CLARET and the White Wines of Bordeaux.

By Maurice Healy. Constable and Co., London. 5 shillings net. 7½ x 4½; 165; 1934.

This volume well maintains the high standard set by the earlier volumes of the Constable Wine Series. The *grands vins* of Bordeaux are, at their best, the superlatively best examples of God's major gift to the gustatory and associated senses of mankind.

[Reginald the Office Boy says this is too strong a statement, likely to lead some paranoiac weaned on Burgundy or Rioja to shoot up the office. He is wrong. We have understated the facts. And in any case magnanimity and reasonableness are our strong points. Should any one feel an urge to prove to us by example that there are better wines than the best of Bordeaux, here we are, ready and waiting. No more willing guinea pig ever offered himself for experimentation!]

Mr. Healy knows his clarets and sauternes, and rates them, on the whole, very fairly and justly. He describes the processes of their growth and manufacture in considerable detail, and gives excellent advice about buying, storing, and serving them. Naturally the bulk of the book goes to the red wines. There isn't much that can be said about a Chateau Yquem of a great year except to be as lyrical as your powers permit, once and for all, and then maintain a reverend peace. It is good to talk about wine, yes, but still better to drink it.

There are some odd biological facts and problems about Bordeaux wines that Mr. Healy touches upon. One of them completely floored Pasteur, by his own admission, after a considerable struggle.



ATTENDING MARVELS. *A Patagonian Journal.*

By George G. Simpson. The Macmillan Co., New York. \$3.00. 9¼ x 6¼; xiii + 295 + 15 plates; 1934.

This is an extremely entertaining book. The author, Associate Curator of Vertebrate Paleontology at the American Museum went to Patagonia to collect fossils, where they grow weird ones for reasons that he makes quite plausible even to those not nurtured on geology. The first thing he did was to run head on into a lively sort of revolution, barely escaping serious consequences. Then with a truck and assorted helpers as time went on he ranged over the pampas, certainly one of the most literally God-forsaken countries in which civilized human beings habitually move and have their beings. The essence of Patagonia is *wind*—lots of it. Air in a tremendous hurry to get somewhere else, in short. And worse, this aerial urge is so nearly perennial as to make no matter.

The author writes both vividly and logically. The result is an amazingly good book, that tells the reader what he really wants to know about the physiography, fauna, flora, the people and their manners and customs, the history, confection and virtues of the national drink *yerba mate*, and a thousand other things. The book is well illustrated with photographs, but unfortunately lacks an index.

THE PHILOSOPHICAL WRITINGS OF LEIBNIZ.
Everyman's Library Volume No. 905.

Selected and Translated by Mary Morris.

E. P. Dutton and Co., New York. 90 cents. 6 $\frac{1}{2}$ x 4 $\frac{1}{2}$; xxxiii + 284; 1934.

This *Everyman's Library* edition of selections from Leibniz's philosophical writings includes the *Monadology*; *Principles of Nature and of Grace, Founded on Reason*; and *On the Ultimate Origination of Things*. These are given complete. In order to show the development of Leibniz's philosophy extracts are also given from his correspondence with Foucher, Arnauld, Bayle and Clarke, and from his *Exposition and Defence of the New System* and *New Essays on the Human Understanding*. Finally in order "to illustrate the breadth and variety of Leibniz's interests, and also his attitude to other men of learning of his time," a number of miscellaneous extracts from his writings are selected. The book includes an introduction by C. R. Morris, a bibliographical note, an annotated index of proper names, and a philosophical index.



SEVEN FAMOUS NOVELS BY H. G. WELLS.
The Time Machine. The Island of Dr. Moreau. The Invisible Man. The War of the Worlds. The First Men in the Moon. The Food of the Gods. In the Days of the Comet.

By H. G. Wells. Alfred A. Knopf, New York. \$2.75. 8 $\frac{1}{4}$ x 5 $\frac{1}{4}$; xi + 860; 1934.

H. G. Wells started what may properly be called his career as a biologist. He has never wholly forsaken the outlook and habits of thought indoctrinated in the South Kensington laboratory. Many of his readers feel that the seven novels here reissued are, taken as a lot, the best work he has ever done. They are, in the order of this edition, *The Time Machine*; *The Island of Dr. Moreau*; *The Invisible Man*; *The War of the Worlds*; *The First Men in the Moon*; *The Food of the Gods*; *In the Days of the Comet*. They are, one and all, biological romances *au fond*, and no one without training in biology can get the full savour of them. The publisher has done a real service in making these stories readily available in beautiful format and at an amazingly low price.



SIXTH REPORT OF THE UNITED STATES
 GEOGRAPHIC BOARD, 1890 to 1932.

U. S. Government Printing Office, Washington. 80 cents. 9 $\frac{1}{8}$ x 5 $\frac{1}{8}$; ix + 834; 1933 (paper).

This report contains all important decisions made by the Board from 1890 up to June 1932. There is an interesting discussion of the problem of making names, and an equally interesting account of the history of the organization. Pages 76-834 are devoted to an alphabetical list of foreign and national geographical names approved by the Board.



THE COST OF BIOLOGICAL BOOKS IN 1934

By JOHN R. MINER

Department of Biology, School of Hygiene and Public Health, Johns Hopkins University

FOLLOWING the usual custom of the QUARTERLY REVIEW OF BIOLOGY the present paper is devoted to a report on the cost of books which have been reviewed during 1934. In a reference in *Nature* to "The Cost of Biological Books in 1933" the question was raised whether the rubric "England" in Tables 1 and 2 did not include books published in Scotland. This is true; we apologize to all good Scotsmen for this unintentional slight and change

published in various countries from 1926 to 1934 and the absolute and relative changes in price from 1933 to 1934 and from 1926 to 1934. Figure 1, plotted on an arithlog scale, compares the price trends for Germany, France, Great Britain and the United States. The average price per page of foreign biological books in terms of United States currency has in general increased from 1933 to 1934. Only the books published by the British Government have shown a decrease in price and these form too small a sample to be reliable. This increase is no doubt attributable, at least in part, to Mr. Roosevelt's noble experiment with the dollar. On the other hand, the trend of price of biological books published in the United States is still downward. As a result of these opposite trends of foreign and domestic books the average price per page of all the books reviewed in 1934 has changed but little, being 1.036 cents, an increase of 3.1 per cent over 1933 but a decrease of 5.6 per cent from 1926.

The price, in terms of the dollar, of books published in Great Britain has increased nearly one-half from 1933 to 1934, but is still 25 per cent below the 1926 price. French books, which until 1933 were the least expensive of any commercially printed books, have increased in price by more than a third from 1933 to 1934, and are now nearly triple the 1926 price. German books are again the most expensive of all. As was noted in the report for 1933 the high prices of German scientific books and periodicals have worked great hardship to both libraries and individual

TABLE 1

Prices of Biological Books, 1934

ORIGIN	TOTAL PAGES	TOTAL COST	PRICE PER PAGE
			<i>cents</i>
Germany.....	7,811	\$147.34	1.89
British-American.....	13,443	195.35	1.45
France.....	12,041	120.22	1.00
Great Britain.....	14,152	135.87	0.96
United States.....	65,959	616.51	0.93
British Government.....	488	4.35	0.89
Other countries.....	6,715	57.75	0.86
U. S. Government.....	3,267	6.00	0.18

the rubric "England" to "Great Britain," and "English-American" to "British-American" with the understanding that in all previous reports these two rubrics include books published in Scotland. The prices of foreign books were converted into dollars on the basis of the exchange at the time the books were received.

The total number of pages reviewed in 1934 is 123,876, an increase of 18.3 per cent over 1933 and of 50.0 per cent over 1926.

Table 2 shows the price trends of books

TABLE 2
Comparison of the Prices of Biological Books from 1926 to 1934

ORIGIN	AVERAGE PRICE PER PAGE									CHANGE + OR - FROM 1926 TO 1934		CHANGE + OR - FROM 1926 TO 1934	
	1926	1927	1928	1929	1930	1931	1932	1933	1934	Absolute	Relative	Absolute	Relative
	cents	cents	cents	cents	cents	cents	cents	cents	cents	cents	per cent	cents	per cent
British-American.....	1.55	1.39	1.46	1.90	1.91	2.27	1.48	1.29	1.45	+0.16	+12.4	-0.10	-6.5
Other countries.....	1.51	0.78	1.13*	1.68	0.97	1.53	1.02	0.85	0.86	+0.01	+1.2	-0.65	-43.0
Great Britain.....	1.28	1.14	1.09	1.29	1.13	1.19	0.89	0.66	0.96	+0.30	+45.5	-0.32	-25.0
United States.....	1.12	1.09	1.14	1.14	1.09	1.05	1.00	1.02	0.93	-0.09	-8.8	-0.19	-17.0
Germany.....	1.09	1.20	1.48	1.65	1.82	1.75	1.60	1.43	1.89	+0.46	+32.2	+0.80	+73.4
British Government...		0.96	1.26	0.39	1.19	1.03	1.45	1.39	0.89	-0.50	-36.0	-0.07†	-7.3†
France.....	0.35	0.36	0.45	0.47	0.47	0.69	0.60	0.74	1.00	+0.26	+35.1	+0.65	+185.7
U. S. Government....	0.31	0.24	0.21	0.23	0.30	0.28	0.36	0.17	0.18	+0.01	+5.9	-0.13	-41.9

* With two special treatises omitted as explained in Vol. 3, p. 601.

† Change from 1927 to 1934.

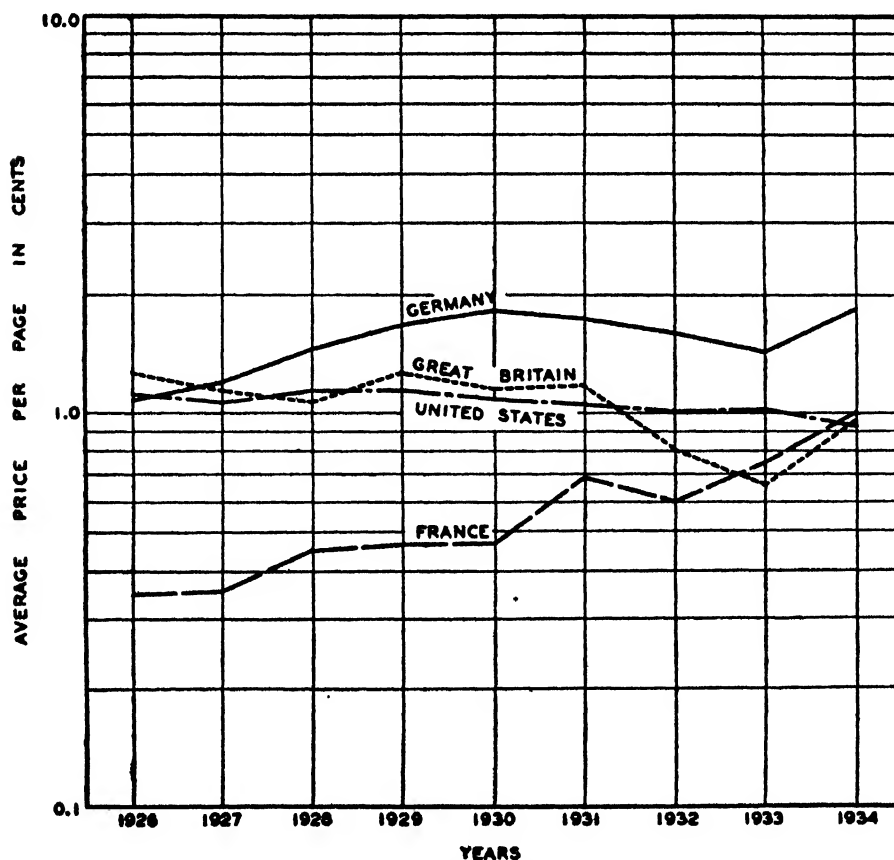


FIG. 2. AVERAGE PRICE PER PAGE IN CENTS FOR BIOLOGICAL BOOKS PUBLISHED IN GERMANY, FRANCE, GREAT BRITAIN AND THE UNITED STATES FROM 1926 TO 1934

scientists; so much so that the Medical Library Association recommended that, unless prices were reduced, libraries should cancel their subscriptions to the most expensive journals. As a result of con-

ferences with the German publishers reductions in the prices of scientific periodicals have been made, but evidently these reductions do not extend to scientific books.



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